Ontario Geological Survey
Miscellaneous Paper 126

Summary of Field Work and Other Activities 1985

Ontario Geological Survey

edited by
John Wood, Owen L. White,
R. B. Barlow and A. C. Colvine

1985

Ontario

Ministry of
Northern Development
and Mines

René Fontaine
Minister
George Tough
Deputy Minister

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Printed in Ontario, Canada

ISSN (Series)0704-2752
ISSN (Sub-series)0829-8203

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Malczak, John
1985: Preliminary Report on the St. Andrew Goldfields and Maude Lake Gold Deposits, District of Cochrane; p.316-319 *in* Summary of Fieldwork and Other Activities 1985, Ontario Geological Survey, edited by John Wood, Owen L. White, R.B. Barlow, and A.C. Colvine, Ontario Geological Survey, Miscellaneous Paper 126, 351p.

1500-85-ALGER

FOREWORD

During 1985, the Ontario Geological Survey carried out a large number of independent geoscience studies. In addition, studies were undertaken in cooperation with the Ontario Ministry of Northern Affairs and Mines and the Ontario Ministry of Natural Resources regional geological staff, personnel from universities, and private consulting firms. Interdisciplinary geoscience programs were also continued in the Opapimiskan Lake and Black River-Matheson (BRIM) areas and are summarized in the section at the end of this report. Project involvement by the various participants is summarized in the individual reports.

Separate funding for a number of regional stimulation projects was provided by the Ontario Ministry of Northern Affairs and Mines, the Government of Canada, and the Ontario Ministry of Natural Resources. Funding acknowledgments are included in the individual summaries.

The locations of the areas investigated are compiled on two maps of the province at the beginning of this report. Preliminary results of field work and other research are outlined in this summary, which contains reports prepared by leaders and principal investigators for each of the projects. In these reports, some emphasis has been placed on the economic mineral resources aspects of the different investigations. The aim of the Ontario Geological Survey is that the information provided will comprise a current database for the mineral resources evaluations of these areas, and so will be a valuable aid to mineral exploration and resource planning in Ontario. In addition, the wide spectrum of research in this report is of interest to the geoscience community as a whole.

Coloured maps and final detailed reports covering most of the field projects are being prepared for publication. In the interim, uncoloured preliminary geoscience maps with comprehensive marginal notes will be released for distribution, mainly during the winter of 1985-1986. Notices of the releases will be mailed to all persons or organizations on the Mineral Resources Group publication release notification list, and will be published in the technical journals and other media.

V.G. Milne
Director
Ontario Geological Survey

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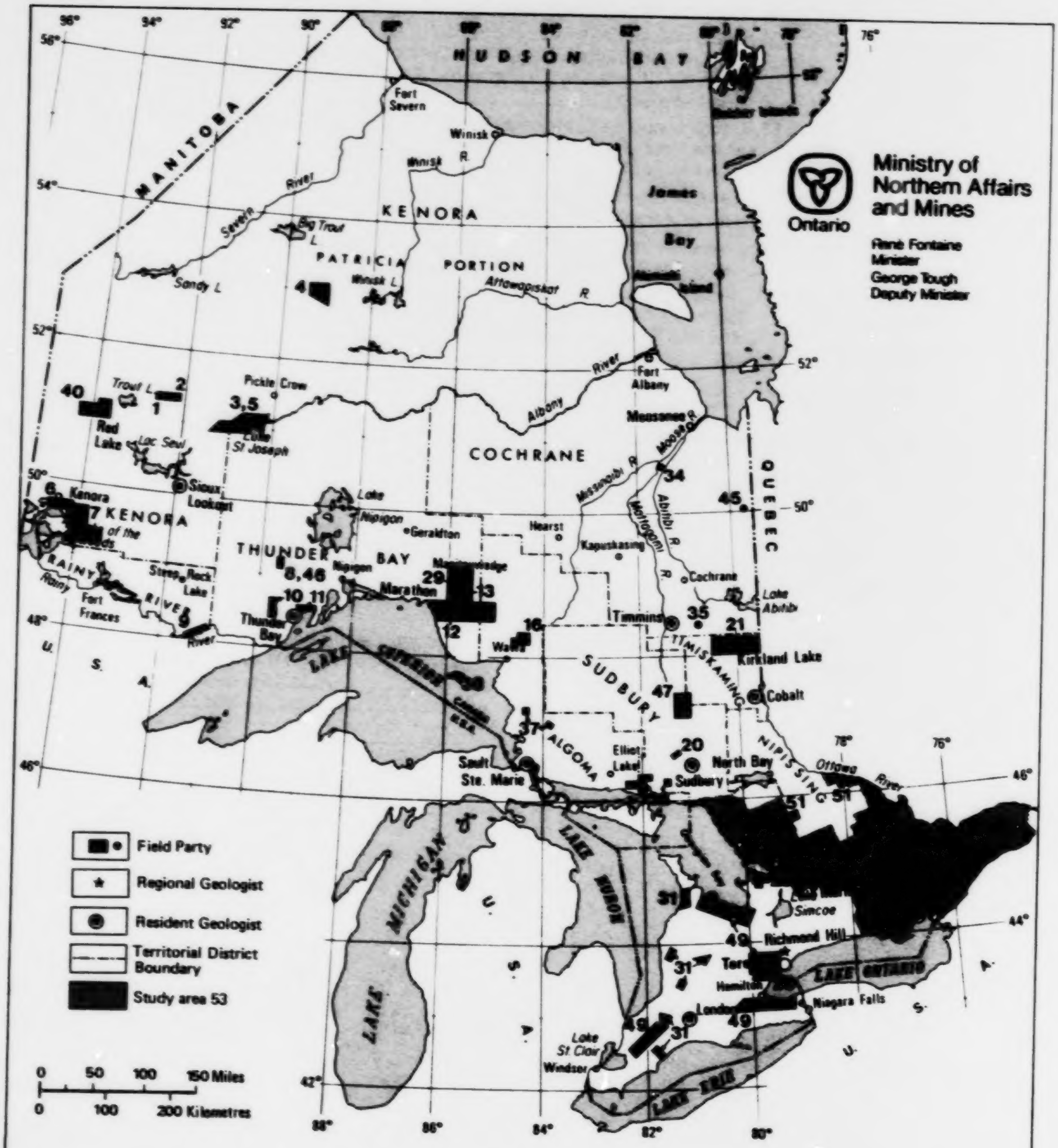

HUDSON BAY
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Belcher Islands
MANITOBA
KENORA
PATRICIA PORTION
COCHRANE
QUEBEC
THUNDER BAY
KENORA
RAINY RIVER
SUDBURY
TIMISKAMING
ALGOMA
NIPISSING
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Winisk
Winisk R.
Severn River
Big Trout L.
Sandy L.
Winisk L.
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Sioux Lookout
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Lake of the Woods
Fort Albany
Albany River
Moosonee
Moose R.
Missinaibi R.
Mattagami R.
Abitibi R.
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Hearst
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Cochrane
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Nipigon
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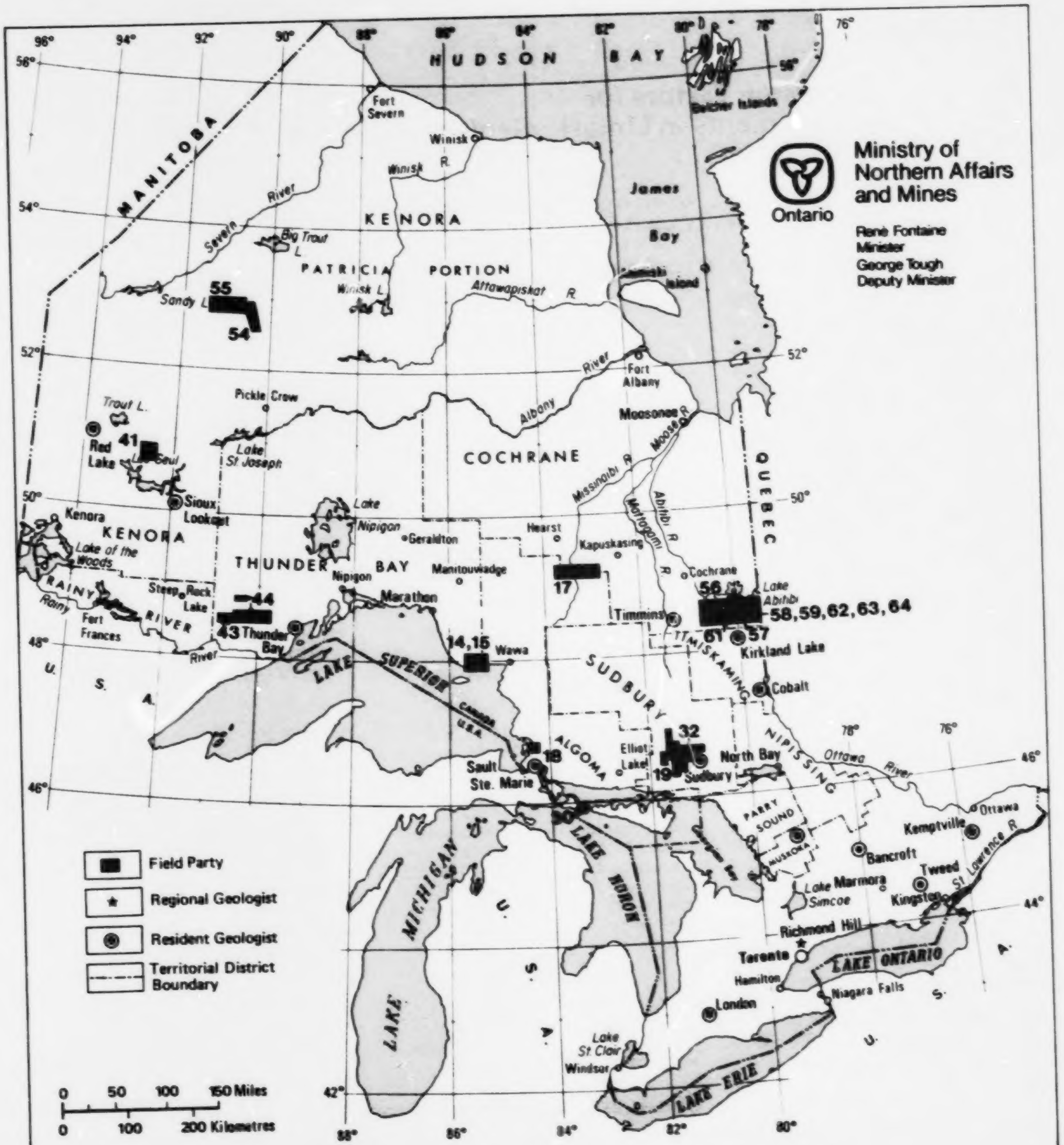
76°
Field Party
Regional Geologist
Resident Geologist
Territorial District Boundary
Study area 53
0 50 100 150 Miles
0 100 200 Kilometres

LOCATION OF FIELD PROJECTS, 1985

ONTARIO GEOLOGICAL SURVEY

Field Projects 24,25,26,36,39,42,48, not shown on map.


HUDSON BAY
Belcher Islands
Ministry of Northern Affairs and Mines
Ontario
René Fontaine
Minister
George Tough
Deputy Minister
MANITOBA
Fort Severn
Winisk
Winisk R.
Severn River
Big Trout L.
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Geraldton
Hearst
Kapuskasing
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Ottawa River
Sault Ste. Marie
PARRY SOUND
MUSKOKA
Ottawa
Kemptville
Bancroft
Tweed
Marmora
Kingston
St Lawrence R.
Lake Simcoe
LAKE MICHIGAN
LAKE HURON
Georgian Bay
Richmond Hill
Toronto
Hamilton
LAKE ONTARIO
Niagara Falls
London
Lake St Clair
Windsor
LAKE ERIE
U. S. A.
Field Party
Regional Geologist
Resident Geologist
Territorial District Boundary
0 50 100 150 Miles
0 100 200 Kilometres
96° 94° 92° 90° 88° 86° 84° 82° 80° 78° 76°
56° 54° 52° 50° 48° 46° 44° 42°

LOCATION OF SUPPLEMENTARY PROJECTS, 1985

MINISTRY OF NORTHERN AFFAIRS AND MINES, ONTARIO
MINISTRY OF NATURAL RESOURCES, ONTARIO
MINISTRY OF TREASURY AND ECONOMICS, ONTARIO
DEPARTMENT OF REGIONAL INDUSTRIAL EXPANISION, CANADA

Field Project 60 not shown on map.

Conversion Factors for Measurements in Ontario Geological Survey Publications

If the reader wishes to convert imperial units to SI (metric) units or SI units to imperial units the following multipliers should be used:

CONVERSION FROM SI TO IMPERIAL			**CONVERSION FROM IMPERIAL TO SI**		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
			LENGTH		
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709 7	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
			AREA		
1 cm²	0.155 0	square inches	1 square inch	**6.451 6**	cm²
1 m²	10.763 9	square feet	1 square foot	**0.092 903 04**	m²
1 km²	0.386 10	square miles	1 square mile	2.589 988	km²
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
			VOLUME		
1 cm³	0.061 02	cubic inches	1 cubic inch	**16.387 064**	cm³
1 m³	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m³
1 m³	1.308 0	cubic yards	1 cubic yard	0.764 555	m³
			CAPACITY		
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
			MASS		
1 g	0.035 273 96	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 75	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 62	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	**907.184 74**	kg
1 t	1.102 311	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 908 8**	t
			CONCENTRATION		
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

1 ounce (troy)/ton (short)	20.0	pennyweights/ton (short)
1 pennyweight/ton (short)	0.05	ounce (troy)/ton (short)

NOTE—Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries published by The Mining Association of Canada in cooperation with the Coal Association of Canada.

PRECAMBRIAN GEOLOGY PROGRAMS

Summary of Activities 1985, Precambrian Geology Section

John Wood

Chief Geologist, Precambrian Geology Section, Ontario Geological Survey, Toronto.

During the summer of 1985 the Precambrian Geology Section undertook 21 field based projects. Of these one was led by Ontario Ministry of Natural Resources regional staff, 2 by graduate students from universities, and the remainder by permanent and contract staff of the Section.

Of these projects, 13 involved detailed (1:15 840 scale) mapping, 1 involves 1:50 000 scale reconnaissance mapping, 2 provide regional (1:50 000 scale) syntheses, 1 is a geological compilation project, and 4 are thematic projects. In some instances there is more than one summary per project.

Detailed mapping at a scale of 1:15 840 provides the fundamental building block for the Precambrian bedrock database. Most of the detailed mapping projects are part of long term programs within a specific area, some however, such as the geology of the Lac des Iles area (Sutcliffe, Project 8), part of a program that will investigate the ultramafic and mafic intrusions in the Wabigoon Subprovince, are thematic. Reconnaissance projects are designed to provide an overview of large areas in order to more effectively focus on specific parts which may require detailed mapping. The projects providing regional syntheses are carried out in areas where detailed mapping has been ongoing for a number of years. Often the mapping of individual map sheets has been carried out by different geologists. The aim of the regional programs is to synthesize the geology and infill any gaps in the detailed mapping. Thematic projects are designed to provide answers to particular geological problems; mapping may or may not be involved.

The Precambrian Geology Section has a long term strategic plan for geological work in the Province of Ontario. This plan is geared towards: (a) providing an ongoing and up-to-date geological database on the Precambrian bedrock of Ontario, and (b) stimulating and guiding mineral resource exploration while remaining cognizant of, and sympathetic to the market place. Over the past few decades the emphasis of the base program of the Section has been strongly geared towards (a); however in recent years, as a reflection of economic necessity, the program has been moving towards (b), bearing in mind that (a) and (b) are not exclusive!

The Ontario Ministry of Northern Affairs, as part of its committment to the mineral resource industry of Northern Ontario, supports and is totally funding four projects; these are: (1) the Opapimiskan Lake interdisciplinary project (Breaks *et al.* Project S54), (2) the Birch Lake (East Half) Project (D.J. Good, Project 2), (3) the Rat Portage Bay Project (J.A. Ayer, Project 6) 4) the Mac Gregor Township Project (J. Scott, Project 11). The Ministry of Natural Resources and the Ministry of Northern Affairs are funding equally the Black River-Matheson (BRIM) interdisciplinary program (Johnstone and Trowell, Project S56).

The support and funds provided by the Ministry of Northern Affairs are gratefully acknowledged by the Precambrian Section. (It should be noted that the Ministry nomenclature used here predates current nomenclature and organization which was put in place during the field season. This has been done in order to clarify the relationships between M.N.R. and M.N.A with respect to the field geological program).

Geographic locations of fieldcrews, ranging from the far northwest to the southeast of the Province, can be seen on the two maps at the beginning of this volume. Rocks of both Archean and Proterozoic age are included. In discussing the results of the Archean geology programs, mention will be made of subprovinces, which are tectono-stratigraphic subdivisions of the Superior Province; their locations are illustrated on Figure 1.

SACHIGO SUBPROVINCE

Activity in the Sachigo Subprovince includes the Opapimiskan Lake interdisciplinary project, and a brief reconnaissance project in the Wunnummin Lake area.

Fred Breaks and Jim Bartlett continued their mapping, initiated last year, of the North Caribou Lake belt. They delineate the distribution of the lithologic units, including various types of iron formation, and present a structural evolution for the

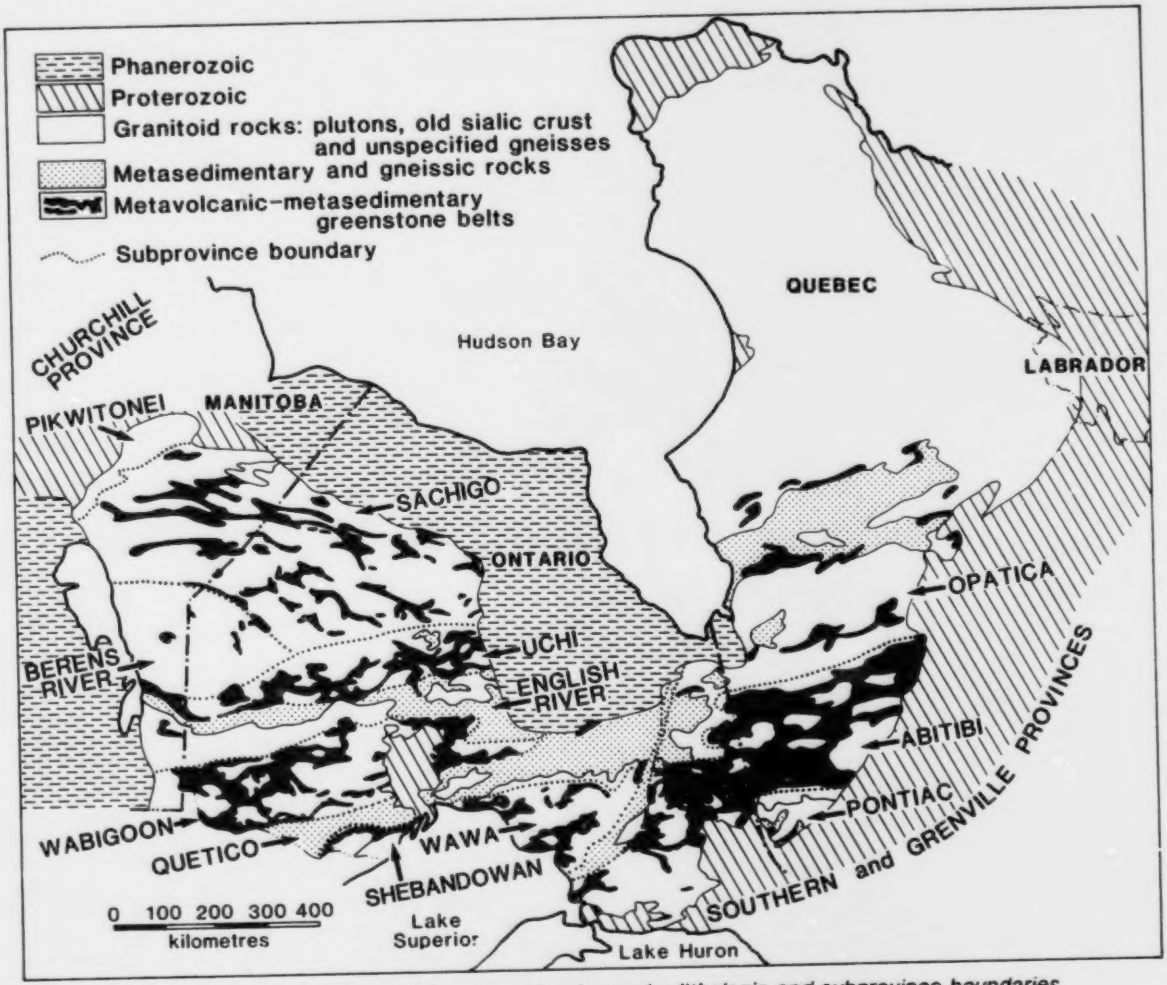
Phanerozoic
Proterozoic
Granitoid rocks: plutons, old sialic crust and unspecified gneisses
Metasedimentary and gneissic rocks
Metavolcanic-metasedimentary greenstone belts
Subprovince boundary
CHURCHILL PROVINCE
PIKWITONEI
MANITOBA
Hudson Bay
QUEBEC
LABRADOR
SACHIGO
ONTARIO
OPATICA
UCHI
ENGLISH RIVER
BERENS RIVER
ABITIBI
PONTIAC
SOUTHERN and GRENVILLE PROVINCES
WABIGOON
QUETICO
WAWA
SHEBANDOWAN
0 100 200 300 400
kilometres
Lake Superior
Lake Huron

Figure 1. Sketch map of the Superior Province showing major lithologic and subprovince boundaries.

belt. They consider that the deposition of gold, which occurs in five distinct habitats, is related principally to one phase of the complex history of the belt; and suggest that the dispersion of K, Rb, and S may be a useful indicator in looking for some types of gold mineralization in the area.

Greg Stott and Don Janes in a short reconnaissance of the Wunnummin Lake belt concluded that previous work in the area was essentially correct. A major shear zone was delineated. The original premise that the Wunnummin Lake and North Caribou Lake belts were structurally and stratigraphically similar is discounted.

UCHI SUBPROVINCE

Over the last 10 to 15 years there has been a continuing Precambrian Section program in the Uchi Subprovince. This started with the work of Riley, then Pirie, then Wallace in the Red Lake area; the work of Pryslak and then Thurston in the Uchi-Confederation Lakes area; the work of Wallace in the Miminiska-Fort Hope area; and in the last few years the work of Stott in the Meen Lake-Pickle Lake area. Wallace is currently integrating the previous work done in the Red Lake area; Thurston has completed such a study on the Uchi-Confederation Lakes area and has in press maps that cover the area of supracrustal rocks between the Red Lake and Uchi-Confederation Lakes belts.

This year's program in the Uchi Subprovince includes detailed mapping in two parts of the Birch Lake area, and regional tectonic and stratigraphic mapping in the Lake St. Joseph area. The positioning of these field crews was in part based on the economic needs of Red Lake, Ear Falls and Pickle Lake. An integration of the geology, especially the stratigraphy, structure, and mineral deposits of the Subprovince within Ontario has begun under the supervision of Henry Wallace.

Gary Beakhouse in the Southwestern Birch Lake area outlines the major lithologic units and structural elements of the area. He considers that proximal felsic volcanics equated by Thurston with Cycle III volcanic rocks in the Confederation Lake area have base metal potential. He recognizes a variety of types of alteration in the area and indicates a number of localities with potential for gold mineralization.

Dave Good shows that the Birch Lake area (Eastern Half) comprises three separate lithologic entities, and that there are at least two major structural breaks within the area. He notes three specific zones where alteration was identified and where the prospects of economic mineralization are good.

Greg Stott and Susan Kay outline four volcanic cycles in the area between Pashkokogan Lake and Lake St. Joseph. Several major folds and faults are described, and an overall tectonic history is outlined. Although some parts of the area appear to have little gold potential, one portion of the map area has a stratigraphic and tectonic setting comparable to the Beardmore-Geraldton area, and a large anticlinal structure in western Lake St. Joseph may hold potential. During the course of field work, pegmatite dikes favourable for economic rare element mineralization were found in several localities, and warrant further work.

WABIGOON SUBPROVINCE

The western Wabigoon Subprovince (west of Lake Nipigon) has been the object of considerable attention from the Precambrian Section over the last 15 years. A relatively high proportion of the supracrustal rocks has been mapped in detail by a number of government geologists, including Blackburn, Davies, and Trowell. Many university and other workers have published on the area. A review of some of the results of these efforts as well as a large scale stratigraphic and structural interpretation are given by Blackburn *et al.* (1985).

The program in the western Wabigoon Subprovince in 1985 included detailed mapping in the immediate area of Kenora; a regional study to integrate the work of a number of geologists in the Kakagi Lake-Rowan Lake area; and detailed mapping of the Lac des Iles complex and adjacent granitoid rocks. All of these projects continue from last year. The Lac des Iles project is part of a multi-year program to study the mafic and ultramafic intrusions in the Wabigoon Subprovince with a view to assessing their mineral potential, especially for platinum group elements. In addition to integrating the regional geology, the project in the Kakagi Lake-Rowan Lake area is attempting a facies analysis of volcanic rocks on a regional scale.

Two of the summaries on the Wabigoon Subprovince are in response to the availability of geochronological data on rock samples collected to solve problems recognized during previous field seasons. For those interested in the evolution of Archean crust in general, and the Wabigoon Subprovince in particular, these two summaries are required reading.

Don Davis of the Jack Satterly Geochronological Laboratory, Royal Ontario Museum, as a follow up to field work in 1982 and 1983 in the Lumby Lake area by M.C. Jackson, undertook sampling for geochronology of several rock units in the Lumby Lake area in 1984. Analyses of these samples indicate that the rocks are almost 3 billion years old; much older than any other rocks previously dated in the Wabigoon Subprovince.

Phil Thurston, currently involved in regional compilation of the Atikokan-Lakehead sheet, which includes a significant portion of the Wabigoon Subprovince, has developed the concept that the Wabigoon Diapiric Axis is a basement complex, and as such is older than and not strictly part of what is currently considered the Wabigoon Subprovince. This is also an interesting and important concept in Archean crustal development.

John Ayer describes the lithologies, stratigraphy, and structure of the Rat Portage Bay area. Clearly, deformation in the area was multiphase and has resulted in complex outcrop patterns. Several schistose, carbonatized, and sericitized shear zones are outlined. Two distinct environments for gold mineralization are proposed; the author considers the area to have good potential for further economic gold mineralization.

Glen Johns tackles and resolves the stratigraphic relationships of a number of formational units in the Kakagi Lake-Rowan Lake area, a region of considerable structural complexity. He also gives a facies analysis of the supracrustal rocks with a view to understanding the paleogeography and evolution of the area. The area has demonstrated potential for economic gold mineralization.

Richard Sutcliffe and Mike Sweeny describe the geology of the Lac des Iles complex which they interpret to have formed by multiple magma emplacement and *in situ* fractionation, considered prerequisites for economic mineralization. They have evidence that granitoid magmatism was coeval with mafic and ultramafic magmatism. A tentative sequence of events, based on surface geology, is given for the development of the platinum-palladium mineralized zone, and based on this, an area of potential, so far essentially unexplored, is outlined.

ABITIBI—WAWA—SHEBANDOWAN SUBPROVINCE

The Abitibi Subprovince, although essentially continuous from beyond the Ontario-U.S. border in the west to Quebec will be considered here as three separate segments: Shebandowan, Wawa, and Abitibi.

SHEBANDOWAN SECTOR

In 1984, the Precambrian Section began a detailed mapping program in the Shebandowan belt after an absence of several years. In 1985, as in 1984, this work consisted of a mapping project west of Thunder Bay, and another such project operated by regional staff close to Thunder Bay. Compilation mapping in 1985 also included this area.

Maurice Carter, in Forbes and Conmee Townships, finds metasediments of the Quetico Subprovince in the northern part of the area separated by a major shear zone from the "Keewatin Type" supracrustal rocks, which include two cycles of volcanic rocks that range in composition from ultramafic to felsic. "Timiskaming Type" supracrustal rocks are present in the central part of the map area. The area has potential for base metals, gold, and silver.

John Scott indicates that MacGregor Township is underlain by a large variety of Archean and Proterozoic rocks, including komatiites. In addition to the already demonstrated silver potential of the area, he considers that the gold potential is good, and indicates a number of localities where further work is warranted.

Phil Thurston, in compilation mapping for the Atikokan-Lakehead sheet, concentrated most of his 1985 efforts in the Shebandowan Sector of the Subprovince. He gives a regional overview of the geology and suggests facies interpretations for some of the supracrustal rocks. A number of areas are suggested for base metal and gold mineralization.

WAWA SECTOR

For some considerable time, the Precambrian Section has had a continuing program in a number of areas within the Wawa Sector of the Abitibi Subprovince. Some of the past workers include Carter in the Terrace Bay area, Muir in the Hemlo area, and Sage and a number of contract geologists in the Wawa area. The program in the last five years has seen Muir return to the Hemlo area to undertake a detailed stratigraphic-tectonic study, Siragusa start a mapping program adjoining Muir's original work, and Sage continue his detailed mapping of the Michipicoten belt in the immediate Wawa area. In 1985, in addition to these projects, a helicopter-supported detailed mapping program was begun in the Mishibishu Lake area.

Georgio Siragusa and Kathy Chivers outline the lithology and structure of the White Lake (Hemlo) area. A large number of gossans were located during mapping; some are extensive, some restricted in size, many appear structurally controlled.

Tom Muir continued his work close to the Hemlo deposit, and gives detailed observations of the supracrustal rocks and their structure. Some of his structural observations have important implications with respect to the stratigraphy and facing direction of the rocks hosting the Hemlo deposit.

Paul Bowen and John Logothetis describe the geology of the Mishibishu Lake area based on a short field season of helicopter-supported mapping. A large variety of supracrustal and intrusive rocks underlie the area. The rocks in parts of the area are extensively sheared. The authors consider that the gold mineralization north of the Mishibishu Lake is structurally controlled. Gold mineralization would appear to be the best exploration bet in the area although potential for base metals and tungsten also exists.

Ron Sage completed mapping of three townships and partially mapped another two in the Wawa area. Several past producers of gold and silver are present in the mapped area. Clearly the area has very good potential for gold mineralization as well as for base metals.

ABITIBI SUBPROVINCE

That part of the Abitibi Subprovince east of the Kapuskasing Structure has received continued attention from the Precambrian Section for many years. Previous workers include Pyke in the Timmins area, Siragusa in the Swayze area, Giblin, Siragusa and Grunsky in the Batchawana area, and Jensen in the Kirkland Lake area.

This year's program included detailed mapping north of Sault Ste. Marie, in the Hearst-Kapuskasing area, and in the Matheson area; and integrative mapping in the Kirkland Lake area.

Peter Born encountered many different Archean and Proterozoic (Huronian and Keweenawan) age lithologies in the Havilland-Goulais Bay area. The area has a long history of structural deformation dating from the Archean to the Phanerozoic. Proterozoic and Phanerozoic fault zones are common. The area contains lead, zinc, copper, and silver mineralization and although no gold mineralization has yet been reported the author considers that such potential exists in the Archean rocks.

Ben Berger mapped a large, heavily drift-covered area in the vicinity of Hearst and Kapuskasing and makes several important additions to previous knowledge of both the bedrock lithology and structure of the area. No occurrences of base or precious metal mineralization are known within the map area, however, this year's work identifies several geological environments which may host economic mineralization.

Rob Johnstone and Norm Trowell continued their mapping in the Matheson area and delineate supracrustal rocks from a number of stratigraphic groups. The greatest mineral potential is for gold. There are past and present producers nearby, and the area contains the Destor-Porcupine Fault Zone, carbonatized ultramafic rocks, pyritic and graphitic sediments, and late felsic intrusions. Base metal potential exists at the interface between two of the rock groups.

Larry Jensen, as part of a continuing integrative mapping program, focused in 1985 on the area between the Round Lake Batholith and the Kirkland Lake-Larder Lake Fault Zone. He introduces some important revisions to the previously known geology of the area and suggests a number of localities and rock types that should be examined in more detail for economic mineralization. This area has good potential for a variety of commodities.

SOUTHERN PROVINCE

The Sudbury area has been the object of considerable recent work by Precambrian Section geologists and other government, industry, and university personnel (Pye, Naldrett and Giblin 1984).

This year there were two projects in the Sudbury area. One in the area north of Agnew Lake was intended to map previously unmapped terrain with a view to delineating any outliers of Huronian rocks, and resolving the structure of the area. The other project continues from previous work on the Sudbury Igneous Complex and has a two-fold purpose: (1) To establish what if any relationship exists between the Footwall Breccia and the Basal Member of the Onaping Formation, and (2) To study in detail, breccias of the Grey and Black Members and "Melt Bodies" of the Onaping Formation; the goal is further understanding of the origin of the Onaping Formation.

Chris Marmont found that in Tofflemire, Venturi, and Vernon Townships there are few outliers of Huronian rocks, but did find interesting relationships between the Spanish River Carbonatite Complex and Sudbury Breccias. The principal mineral potential would appear to lie with the carbonatite.

Peter Brockmeyer and Rolf Lakomy started work on the Onaping Formation and the footwall breccia of the Sudbury Igneous Complex, an exceptionally complex and complicated collection of rocks. Considerable emphasis will be placed on petrology, geochemistry, and statistical analysis of clast abundances, sizes and shapes.

GRENVILLE PROVINCE

The Precambrian Section has had a continuing program in the Central Metasedimentary Belt of the Grenville Province for many years. Workers have included Bright, Wolff, Themistocleous, Pauk, Moore, Bartlett and others. For the last three years Easton has been mapping in the general Minden area. This program continued this year, also, specific work was done on anorthosites in the Grenville Province.

Mike Easton continued mapping and definition of the Central Metasedimentary Belt rocks in the Lochlin area. The rocks in this area have been extensively tectonized. The area has potential for uranium and thorium, gold, niobium and yttrium, and rare earth elements, as well as nonmetallic commodities such as marble, amphibolite gneiss (road metal), various aggregate materials, and flagstone in addition to Quaternary and Recent sand and gravel deposits.

Martin Van Kranendonk studied anorthositic units in two areas of the Central Gneiss Belt, and in the Denna Lake Structural Complex (Easton, this volume) to help in resolving two different interpretations for their origin and to assess their mineral potential, which would appear to be principally as building stone.

COMPUTER SOFTWARE

As part of the Section's committment to making available all information that may be of help to the public, the final summary by Elizabeth Ambrose, Danny Wright and Eric Grunsky is an update on Computer Software available in the Section.

The reports contained in this volume represent a first appraisal of raw geological field data, as do the preliminary maps which are in preparation for publication during the 1985-86 winter period. The summaries and maps are designed as a means to rapidly disseminate "highlights" and to present general outlines of new information. Extended analysis of field data in conjunction with detailed office and laboratory research, for final report and map publication, can be expected to result in changes to the field terminology, interpretations, and concepts expressed in this summary.

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1. Geology of the Southwestern Birch Lake Area, District of Kenora (Patricia Portion)

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INTRODUCTION

The southwestern Birch Lake area is centred approximately 95 km east-northeast of the town of Red Lake. The project area lies between Latitudes 51°16′40″N and 51°22′50″N, and Longitudes 92°39′26″W and 92°22′00″W, and covers approximately 190 km^2. This project and that currently underway in the area immediately to the east (*see* Good, this volume) begin a multi-year detailed mapping program focusing on the geology and mineral potential of the Birch Lake Belt. Although the project area has never been mapped in detail, it has been the subject of several reconnaissance mapping projects (Harding 1936; Thurston *et al.* 1981).

Access is by float-equipped aircraft from Red Lake, and within the map area movement is facilitated by extensive waterways and numerous portages, most of which are in relatively good condition.

Except for the eastern part of the map area where they constitute <1% of the surface area, outcrop exposures are generally abundant but unevenly distributed. Examination of lakeshore exposures was hampered by record high water levels.

MINERAL EXPLORATION

Early mineral exploration (1925 to 1936) in the Birch Lake area focused on gold mineralization. Base metal exploration received increased emphasis following the discovery in 1968 of the South Bay Cu-Zn-Ag deposit which is situated approximately 25 km south-southwest of the map area. Harding (1936) and Thurston *et al.* (1981) summarized these and other mineral exploration activities.

Recent mineral exploration activity in the Birch Lake area has again focused on gold. At the time of writing, approximately 60% to 70% of the ground in the map area was staked with most of the open ground being in the western part of the map area. St. Joe Canada Incorporated, Kidd Creek Mines Limited, Labrador Mining and Exploration Company Limited, and Noranda Exploration Company Limited are among the companies and individuals holding, either directly or under option agreements, large claim groups and were active in the area during 1985.

GENERAL GEOLOGY

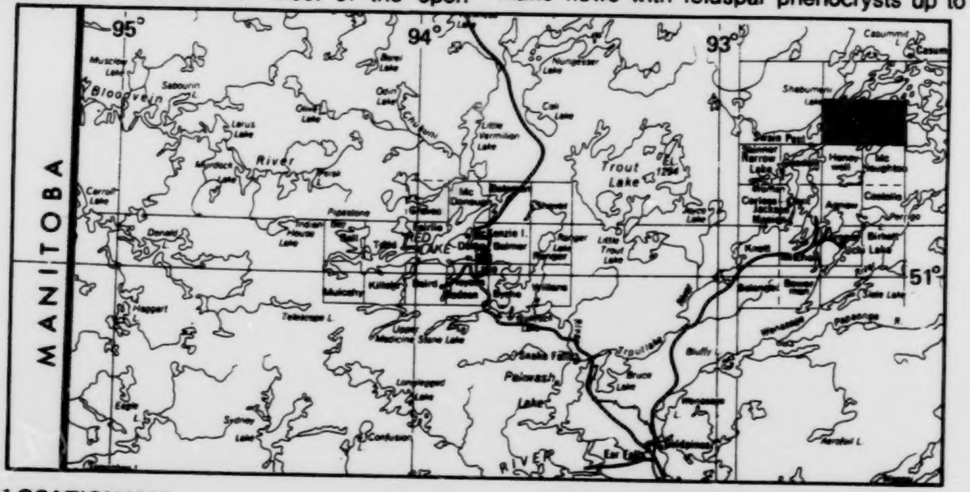
All of the bedrock in the area is inferred to be of late Archean age. Thurston (in preparation) has tentatively correlated various sequences around Birch Lake with the volcanic cycles recognized in the Confederation Lake area to the south, where volcanism is known to range in age from 2960 Ma to 2740 Ma (Nunes and Thurston 1980).

A major northeast-trending fault, referred to as the Swain Lake Fault (Goodwin 1967; Thurston, in preparation), bisects the map area and separates areas characterized by contrasting lithologies and structural styles (Figure 1). Supracrustal lithologies from each of these areas are discussed separately below.

NORTHWEST OF SWAIN LAKE FAULT

The area to the northwest of the Swain Lake fault is characterized by northeasterly trending stratigraphy and structures. Mafic, intermediate, and felsic volcanic rocks are all well represented while metasediments constitute a minor part of the sequence.

Mafic metavolcanics are most abundant in the northern part of this area where they comprise massive and pillowed flows. Medium grained gabbros associated with these metabasalts are either thick flows or sills; in the latter case, these units are likely closely associated with mafic volcanism. Porphyritic mafic flows with feldspar phenocrysts up to 3 cm in



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

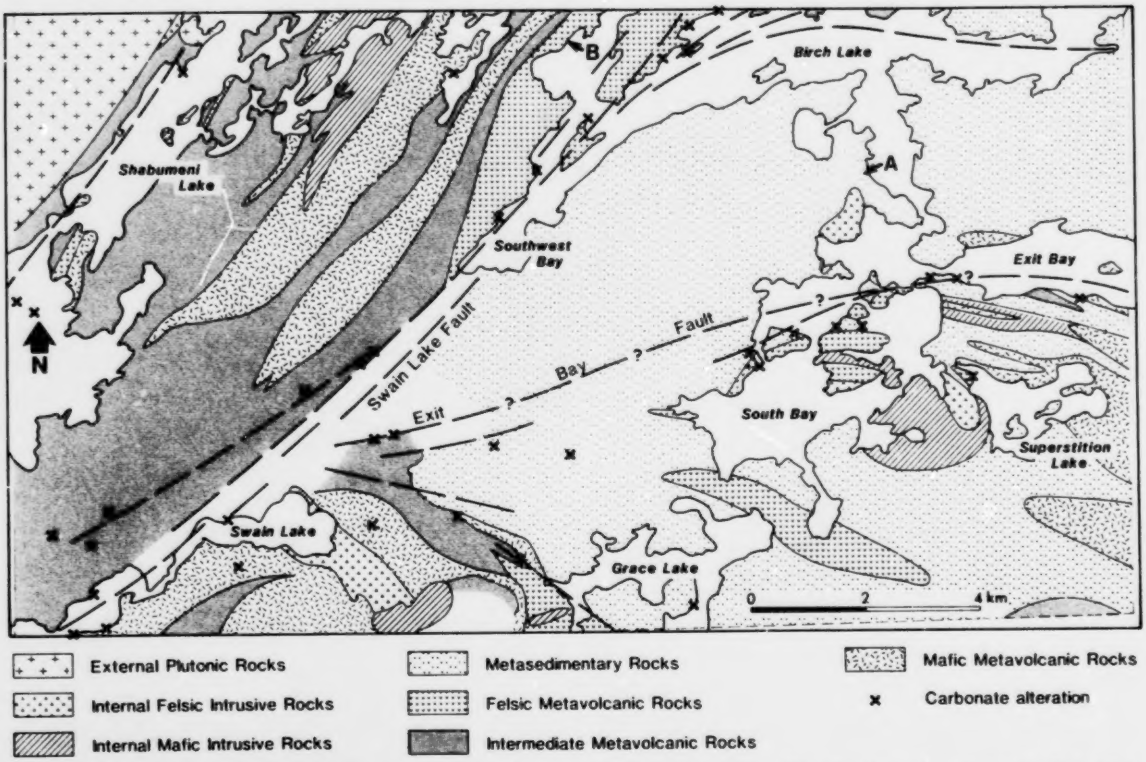

Birch Lake
B
Shabumeni Lake
A
Southwest Bay
Exit Bay
N
Swain Lake Fault
Exit Bay Fault
?
South Bay
Superstition Lake
Swain Lake
Grace Lake
0
2
4 km
External Plutonic Rocks
Internal Felsic Intrusive Rocks
Internal Mafic Intrusive Rocks
Metasedimentary Rocks
Felsic Metavolcanic Rocks
Intermediate Metavolcanic Rocks
Mafic Metavolcanic Rocks
Carbonate alteration

Figure 1. *Generalized geological map of the southwest Birch Lake area. Distribution of units near the map boundaries is based in part on information compiled from Pryslak (1973), Johns (1979), and Good (this volume). (Project 1.)*

diameter are common in the more easterly mafic volcanic units.

Intermediate volcanic rocks are more abundant in the southern part of the area where they consist mainly of pyroclastic deposits and subordinate flows. The fragmental deposits include tuff-breccia, lapilli-tuff, and tuff. Tuff-breccias and lapilli-tuffs are compositionally monolithic, consisting largely of intermediate (dacitic?) volcanic fragments which exhibit a wide range of textures reflecting variations in phenocryst (plagioclase and/or amphibole) content and intensity of alteration.

Felsic metavolcanics consist of massive to flow banded and/or auto-brecciated flows and tuffaceous rocks ranging from coarse, massive tuff-breccia to thinly bedded fine grained tuffs. Quartz and/or feldspar phenocrysts are common in these units. These rocks occur in three settings:

1. In the north-central part of the map area, flows and coarse fragmental deposits form part of a large felsic volcanic centre, most of which lies to the north of the map area (Thurston *et al.* 1981).
2. As numerous, small discontinuous lenses lying principally in the largely, intermediate sequence in the southwestern part of the map area.
3. As a narrow thinly bedded rhyolitic unit associated with cherty chemical sediments that can be traced through the central part of Shabumeni Lake.

Metasediments are not abundant within this sequence. Chert, ferruginous chert, and banded chert-magnetite ironstone occur principally on the islands in Shabumeni Lake and along the Shabumeni River. Clastic metasediments intercalated with the metavolcanics probably represent local reworking of volcanic deposits.

SOUTHEAST OF SWAIN LAKE FAULT

The area to the southeast of the Swain Lake Fault is lithologically more diverse and structurally more complex than the area described above. Metasediments predominate over metavolcanics in contrast to the paucity of metasediments northwest of the Swain Lake Fault.

The largest area underlain by mafic metavolcanics lies south and east of Swain Lake. Massive and pillowed flows are common, and distinctive variolitic metabasalts occur locally south of Swain Lake. Between Exit Bay and Superstition Lake, predominant medium grained mafic rocks which may be either flows or sills occur together with subordinate massive and pillowed fine grained flows. Elsewhere, thin fine grained mafic units interpreted as mafic metavolcanics are commonly characterized by in-

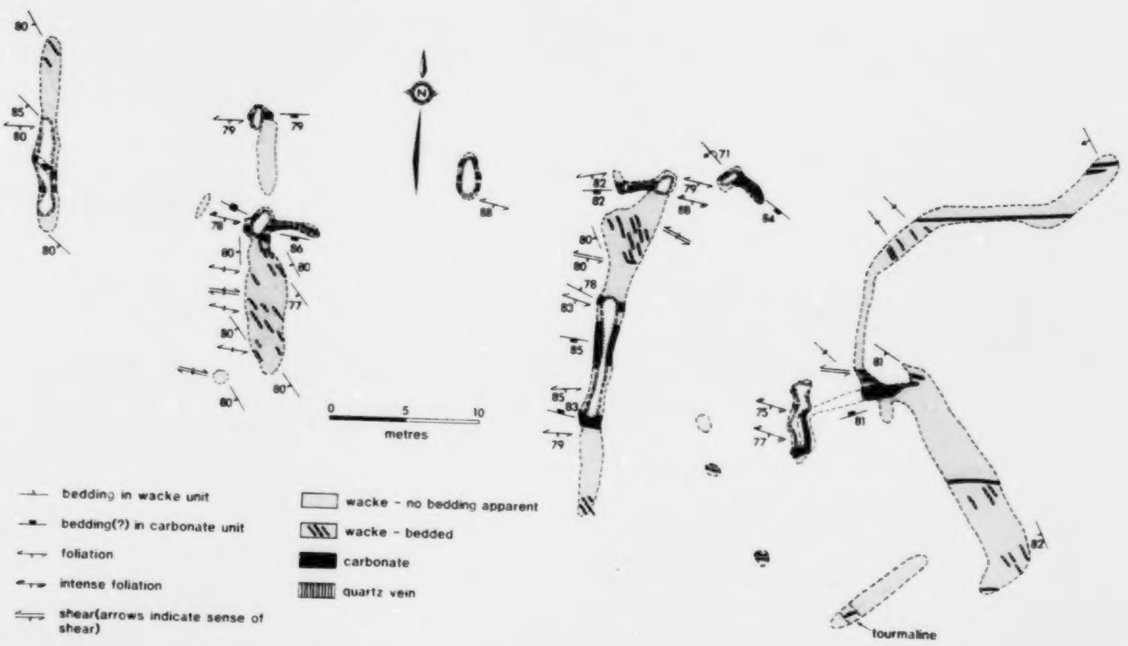


***Figure 2.** Geologic map of a part of the Greencamp Property (location A, Figure 1). (Project 1.)*

tense fabric development which has obliterated primary structures.

Felsic metavolcanics include flows that commonly display flow banding and/or auto-brecciation, and monolithic pyroclastics. Certain of the finer grained, crystal (quartz and/or feldspar) rich varieties, which contain sparse lapilli-sized lithic fragments and possible pumice fragments, may represent ash-flow tuffs.

Intermediate volcanic rocks are not abundant and are predominantly pyroclastic deposits showing various degrees of reworking.

Clastic metasediments include: wackes which are commonly thinly laminated to medium bedded (<30 cm) and displays sedimentary structures (Bouma cycles, grading, scour, ripple cross-laminations) that suggest deposition from turbidity currents; arenites which are commonly more thickly bedded and lack the sedimentary structures common in the wackes; and massive to crudely bedded polymictic conglomerates which contain clasts (up to 1 m^2 in cross-sectional area) of mafic, intermediate, and felsic volcanic rocks, chemical sediments, porphyries, and vein quartz. The arenites are commonly associated with the conglomerates, but there appears to be a compositional continuum between wacke and arenite.

Chemical metasediments include magnetite iron formation units that occur interlayered with wackes south of Grace Lake and thinly bedded chert-magnetite iron formation interbedded with metabasalt east of Swain Lake. Calcitic carbonate units within wacke near the channel into South Bay are provisionally interpreted as sedimentary carbonate although they are oriented parallel to the tectonic fabric and are discordant to the regional trend of bedding. In detail, shearing has locally transposed and oblitered bedding in wacke adjacent to the carbonate units. The unique physical properties of the carbonate has served to localize intense deformation and transposition of bedding (Figure 2) which subsequently focused the hydrothermal fluid flow responsible for quartz veining and gold mineralization.

INTRUSIVE ROCKS

Rocks intrusive into the supracrustal sequences of the map area include external, medium to coarse grained, felsic plutons and internal, fine to medium grained mafic and felsic stocks, plugs, and dikes. External plutons which bound the Birch Lake supracrustal belt to the west, north, and east are restricted to the extreme northwestern corner of this map area, where they consist of medium to coarse grained, commonly megacrystic (microcline) biotite ± hornblende granodiorite.

Internal felsic intrusions are commonly fine grained and are interpreted to have been emplaced at shallow depth. Equigranular varieties occur but many are porphyritic, containing one or more of quartz, feldspar (plagioclase), or amphibole phenocrysts. Mafic intrusions are typically medium grained except near their margins; most are equigranular and have gabbroic compositions.

STRUCTURE

The Swain Lake Fault bisects the map area into two domains which, in addition to the lithological contrasts discussed above, also have differing structural styles. To the northwest of the fault, both foliation and bedding have northeast to north-northeast regional trends and steep, generally northwesterly dips.

The paucity of reliable facing indicators throughout much of this sequence prohibits delineation of any major folds that might exist. Intensity of fabric development is heterogeneous, being concentrated in discrete zones concordant with respect to stratigraphy. These zones may represent either strike faults or lithologic units that have been relatively susceptible to recrystallization due to their mineralogy.

Southeast of the Swain Lake Fault, the orientation of bedding and, to a lesser extent, foliation are highly variable. Foliation exhibits a general convex-northward pattern being oriented east-northeast near the Swain Lake Fault, east-west west of South Bay, and east-southeast east of South Bay. Bedding exhibits a similar general trend but with many more irregularities. In several areas (eg. northwest of South Bay), bedding is at a high angle to foliation in the noses of folds. Some of the irregularities in orientation of foliation and the local development of two tectonic fabrics are interpreted to be related to faults which trend east-northeasterly and west-northwesterly.

The Swain Lake fault is a major deformation zone up to 1 km wide which extends an unknown distance beyond the map area. This zone is poorly exposed, lying principally beneath the waters of Swain Lake, the southwestern bay of Birch Lake, and beneath small lakes and swamp deposits between Birch and Swain Lakes. It is best regarded as a fault system with numerous splays, and consisting of intensely sheared zones alternating with less intensely deformed rocks. The intensely sheared rocks are characterized by a single strong planar fabric; these grade into progressively less deformed rocks that exhibit a single anastomozing fabric or two intersecting fabrics that surround lenses of less deformed material. Iron carbonate alteration is commonly associate with strong planar fabric development, and quartz (± carbonate ± tourmaline) veins are associated with the less deformed rocks adjacent to the planar shears.

A second major fault that forms a splay off the Swain Lake Fault is postulated to extend east-northeastward from a point just north of the eastern end of Swain Lake to Exit Bay. This is inferred on the basis of airphoto lineaments, local intense fabric development and associated carbonate alteration, and possible truncation of lithologic units. Further work is required to document the existence and nature of this fault.

ALTERATION

Types of alteration recognized in the map area include carbonatization, silicification, and epidotization; all three occur both as veining and diffuse pervasive alteration. Although minor alteration is ubiquitous, intense alteration is geographically restricted and related to specific structures and/or lithologies.

Carbonatization (predominantly iron carbonate) is commonly associated with zones having an intense planar fabric interpreted to be faulting induced. Outside these zones, carbonate is more commonly calcitic and occurs principally in veins, as opposed to the veining plus pervasive diffuse alteration found within the highly deformed zones.

Epidotization and silicification occur principally in mafic and intermediate metavolcanics. The most extensive areas of such alteration occur around the felsic stock at the eastern end of Swain Lake.

Quartz (± carbonate ± tourmaline) veining is widespread but is especially abundant in gabbros, relatively fine grained felsic intrusive rocks and wackes adjacent to carbonate units which are relatively susceptible to brittle fracture, and in relatively weakly deformed rocks adjacent to zones of intense planar fabric development.

ECONOMIC GEOLOGY

The map area has high potential for the discovery of base metal massive sulphide and gold deposits.

The most favourable environments for base metal massive sulphide deposits are the lenses of felsic metavolcanics. Two of these (the large felsic unit in the north-central part of the map area and that between Birch and Grace Lakes) have a high proportion of flows and coarse pyroclastic deposits indicating proximal facies. Thurston (in preparation) has tentatively correlated both of these units with Cycle III in the Confederation Lake area which hosts significant Cu-Zn-Ag deposits.

The most favourable environments for gold mineralization include: (1) sheared zones associated with major faults and local heterogeneous deformation, especially where these have associated alteration, veining, and/or disseminated sulphide mineralization, and (2) areas within and marginal to fine grained felsic stocks.

Major fault zones which have high gold potential include the Swain Lake Fault and the postulated Exit Bay Fault. Specific targets within the former include areas of iron carbonate and pyritic alteration in zones of intense planar fabric development, and quartz veins, with or without associated carbonate, tourmaline, and sulphide mineralization; such veins tend to be concentrated marginal to the zones of intense planar fabric development. One quartz-carbonate-tourmaline vein with minor associated sulphides collected during this survey (location B, Figure 1) assayed 12.73 ounces gold per ton and 1.77 ounces silver per ton (analyses by Geoscience Laboratories, Ontario Geological Survey, Toronto).

Gold may also occur in association with veining and/or alteration developed in localized zones of shearing or brittle fracturing which are commonly found in zones of lithologic heterogeneity. Gabbros and fine grained felsic intrusive rocks are especially susceptible to brittle fracture and commonly contain veins. At the Greencamp property (Figure 2), extreme ductility contrast between wacke and probable carbonate metasediment appears to have played a role in localizing shearing, transposition of bedding and quartz veins containing erratic gold mineralization.

High level felsic stocks may also host gold mineralization. Gold mineralization within or marginal to such stocks is recognized on Pants Island (north of narrows into South Bay), on the northern shore of South Bay, and west of Superstition Lake. It is not clear in these examples if gold mineralization was temporally associated with the intrusive event. Alternatively, the presence of the stocks within more ductile rocks may have promoted heterogeneous deformation which served to focus post-emplacement fluid migration as discussed above.

In summary, the most favourable environments for gold mineralization include deformation zones associated with major faults and high level felsic stocks especially where these are associated with alteration and veining.

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2. Birch Lake Area (Eastern Half), District of Kenora (Patricia Portion)

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INTRODUCTION

The Birch Lake area (eastern half), is centred approximately 120 km northeast of Red Lake. The area is part of the northeastern extension of a major Archean supracrustal mass referred to as the Birch-Uchi Belt. Mapping in this first year of a two-year project covered the southern half of the area, bounded by Latitudes 51°15'00"N and 51°22'30"N, and Longitudes 92°06'00"E and 92°23'00"E. An area of similar size immediately west of this project is currently being mapped by Beakhouse (this volume).

Access is by float-equipped aircraft from Red Lake. Canoe access is possible from the South Bay Road which extends north from Highway 105 at Ear Falls, but, requires several portages. Within the map area, canoe access is possible along an extensive interconnected lake and river system. Birch Lake drains through Exit Bay into the Birch River which then flows through Satterly, Cromarty, and Springpole Lakes. Seagrave Lake drains into the Birch River. The topographic relief in the area is generally <40 m, consequently outcrop exposure is generally low, but, varies considerably.

MINERAL EXPLORATION

Several exploration companies are actively exploring for gold around Birch, Springpole, and Seagrave Lakes. Exploration in the area intensified in 1984 and 1985 following a base metal discovery at the northwestern end of Superstition Lake, and the report of favourable gold assays from near the portage between Springpole and Birch Lakes (M.J. Lavigne, Resident Geologist, Ontario Ministry of Northern Affairs and Mines, Red Lake, personal communication, 1985). Properties in the area have recently been acquired, or examined, by several exploration companies including Dejour Mines Limited, Dome Exploration Limited, Gold Fields Mining Corporation, Lacana Mining Corporation, Noranda Exploration Company Limited, Phantom Exploration Limited, and B/P Selco-Canada Limited.

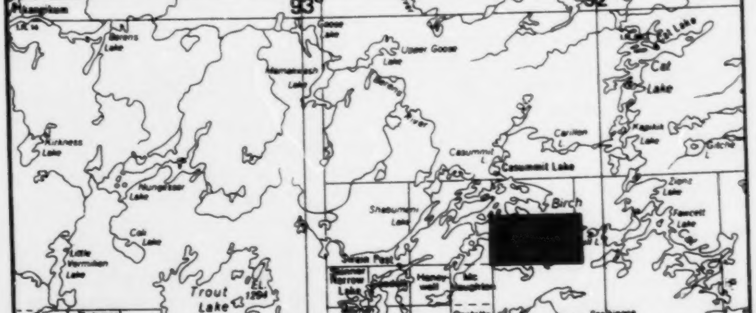
Information on exploration activity, prior to 1984, summarized below is taken from the Resident Geologist's Files, Ontario Ministry of Northern Affairs and Mines, Red Lake.

In 1983, Labrador Mining and Exploration Company Limited conducted electromagnetic and magnetic surveys on the Tom Group of claims between Exit Bay and Wagner Bay of Birch Lake. At least five strong conductive zones trending northwest-southeast were outlined.

In 1979, Sherritt Gordon Mines Limited diamond drilled three holes on their claim block just west of Graydarl Lake. They reported veins and lenses of carbonate with pyrite plus pyrrhotite crosscutting mafic to felsic tuff and flows, as well as pelitic sediments. Assays reported for the mineralized zones showed only trace values of gold, but, up to 0.28 ounce silver per ton.

In 1973, Amax Exploration Incorporated conducted an AEM survey over the Seagrave Lake area flown at 1000 feet line spacing. Four anomalies were detected, and a small claim group was staked over each. VLF-EM and magnetometer surveys were then conducted on each claim group. The eastern and southern groups showed strong east-west trending conductors.

In 1970, Sudbury Contact Mines Limited conducted a magnetic and electromagnetic survey on their property along the northwestern shore of Springpole Lake. They found scattered magnetic anomalies, apparently due to magnetite in the mafic metavolcanics. The electromagnetic survey picked up three weak conductors which are apparently not associ-



LOCATION MAP

Scale: 1:1 548 000 or 1 inch to 25 miles

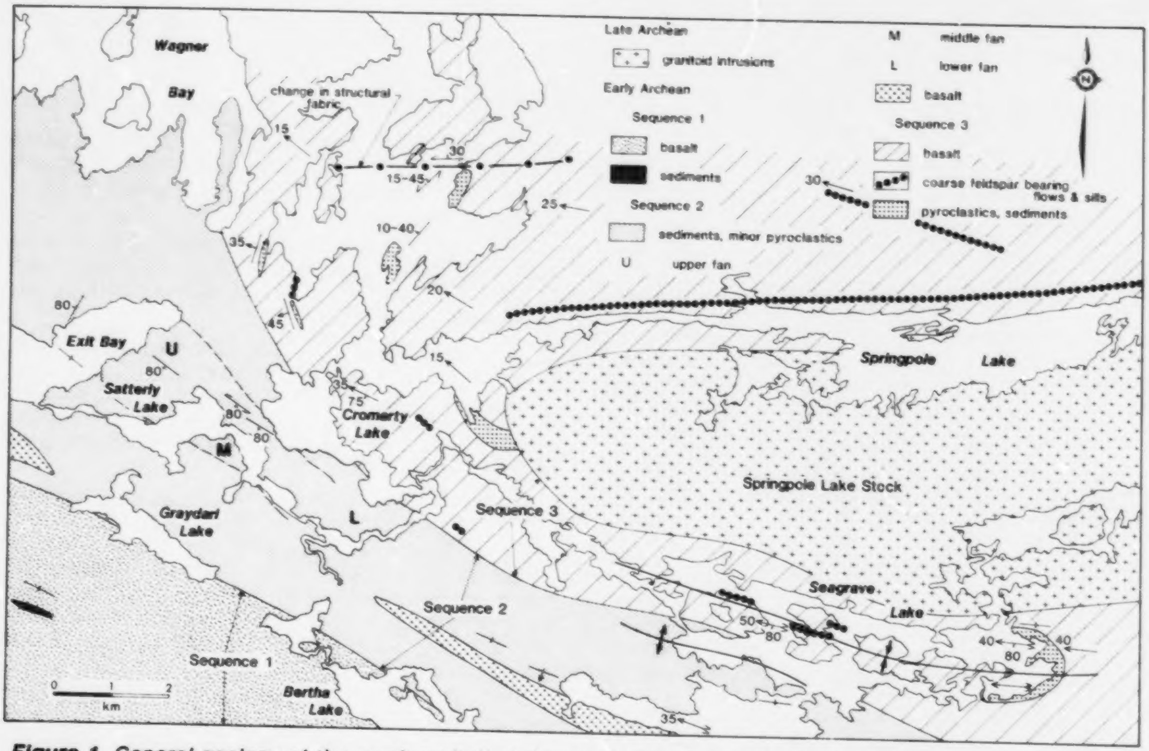

Wagner
Bay
change in structural fabric
15
30
15–45
25
10–40
35
20
45
80
Exit Bay
U
80
Satterly
Lake
80
80
M
15
35
75
Cromerty
Lake
Graydarl
Lake
L
Sequence 3
Sequence 2
Sequence 1
Springpole Lake Stock
Springpole
Lake
Seagrave
Lake
50
80
40
40
80
35
Bertha
Lake
0
1
2
km
Late Archean
granitoid intrusions
Early Archean
Sequence 1
basalt
sediments
Sequence 2
sediments, minor pyroclastics
U
upper fan
M
middle fan
L
lower fan
basalt
Sequence 3
basalt
coarse feldspar bearing flows & sills
pyroclastics, sediments
30
N

Figure 1. General geology of the southern half of the Birch Lake East area. (Project 2.)

ated with the magnetic anomalies and further investigation was recommended.

GENERAL GEOLOGY

The map area is underlain by rocks of Archean age, which are locally covered by glacial deposits. The general geology of the area is shown in Figure 1.

The area is divided into three northwest-southeast trending stratigraphic Sequences characterized by predominance of either metasediments plus pyroclastics or mafic metavolcanics. The first Sequence lies southwest of Graydarl Lake and consists mainly of mafic metavolcanics with minor interlayered pelitic sediments. These metavolcanics are dark green to black and frequently contain biotite and/or tourmaline. They occur as massive unpillowed flows in places separated by flow breccia.

The second Sequence which stretches from Wagner Bay of Birch Lake through Satterly Lake into Seagrave Lake, consists, in decreasing order, of metasediments, pyroclastics, and mafic metavolcanics. Within this Sequence, the rocks north of Exit Bay are predominantly sandy to pelitic sediments with minor intermediate tuff and lapilli-tuff. The sediments generally consist of thinly bedded wacke-siltstone showing AE Bouma subdivisions of turbidites, and, massive sandstone with thin interbedded wacke-siltstone. Southeastward from the southern shore of Exit Bay Sequence 2 changes considerably along strike. From Exit Bay through Satterly Lake it consists of chaotic matrix-supported conglomerates and primary pyroclastics of intermediate to mafic composition. The conglomerates commonly contain reworked pyroclastic material along with clasts of felsic to mafic metavolcanics, granitic rocks, iron formation, and quartz. Farther to the southeast along strike the pile grades first into well sorted, or graded, conglomerates with interlayered pelitic, units and, finally into thinly bedded wacke-mudstones commonly showing AE Bouma subdivisions characteristic of turbidites. The above evidence suggests a full upper fan to lower fan relationship for a submarine fan environmental model (Walker 1979, p.98). The pyroclastics in the upper fan environment could be part of the intermediate-source facies of a nearby volcanic centre (Fisher and Schminke 1984, p.359).

At Seagrave Lake, pyroclastics consisting of intermediate to felsic lapilli-tuff and crystal tuff dominate the northern part of Sequence 2. Interlayered with the pyroclastics are thinly bedded units of siltstone.

Sequence 3 lies northeast of Sequence 2, and consists mainly of mafic metavolcanics with thin shallow dipping interlayered units of pelites and pyroclastics. The package of mafic metavolcanics comprise several continuous sills and flows containing layers rich in coarse feldspar crystals (up to 15 cm in length). The spacing of these feldspar-rich units through Sequence 3 suggests most of the basalts in Sequence 3 are co-magmatic. Basalts containing similar coarse feldspars also occur close to the portage from Springpole to Birch Lake, and just south of Johnson Island on Birch Lake. This suggests a possible correlation of Sequence 3 from Seagrave Lake through to Birch Lake.

The Springpole Lake Stock intrudes the metavolcanics and metasediments of Sequence 3 between Seagrave and Springpole Lakes. The body is zoned from a narrow biotite monzodiorite/quartz diorite rim to a biotite quartz monzonite/granodiorite core. Mafic metavolcanics along the northern and western edge of the intrusion are weak to moderately hybridized due to the injection of granitic material along planes of foliation in the basalt.

Across the map area the volcanic rocks have been metamorphosed to predominantly greenschist facies. However, contact metamorphism around the granitic intrusion, noted above, has upgraded the supracrustal rocks to amphibolite facies. In the central part of the western arm of Springpole Lake, flows are characterized by thin amphibole layering trending northeast and dipping northwest.

Magnetic trends across the map area usually parallel stratigraphic and structural features. Strong magnetic anomalies can be related to magnetite-rich metabasalts, and in one case a chlorite alteration zone with magnetite/pyrite mineralization. Iron formation outcrops on Birch Lake and Bertha Lake, but, in other areas it can be inferred because of narrow magnetic highs within areas underlain dominantly by deep water sedimentary rocks.

STRUCTURAL GEOLOGY

Structural geology in the area is dominated by northwest-southeast trending folds which plunge to the northwest. The fold axes (280° to 310°, plunging 15° to 50°) of parasitic folds are parallel to mineral and clast lineations across the map area. At Seagrave Lake, numerous, well exposed, symmetrical parasitic folds, strong axial planar cleavage, and stratigraphic, as well as magnetic patterns indicate a synform/antiform pair passing through the middle of the lake. However, evidence for this pair is lacking near Cromarty Lake.

A distinct structural break trending northeast-southwest through Exit Bay and into Springpole Lake disrupts the continuous structural pattern mentioned above, but northwest-trending mineral elongations north and south of this zone remain essentially parallel. Within this zone foliation (025° to 045°, dipping 10° to 30° northwest) is roughly parallel to bedding. A magnetic anomaly trending east-west through Springpole Lake marks the northern extent of this zone where structural fabric trends changes from northeast to east-west.

Along the northern shore of the eastern arm of Springpole Lake, the foliation trends east-west and dips 25° to 60° to the north. There are also several examples of horizontal parasitic folds with axial planes dipping parallel to the foliation just mentioned. The orientation of these folds is probably related to the emplacement of the granitic intrusion to the south, but, further information is needed to determine the nature of this relationship.

The regular east-west trending stratigraphy and structural fabric immediately north of the eastern arm of Springpole Lake is weakly folded about northeasterly plunging fold axes at the western end of Springpole Lake.

ECONOMIC GEOLOGY

There are several gold-bearing mineral deposits in the Birch Lake area, two of which, located immediately north of the map area, were previously mined. The Argosy Mine on Casummit Lake was mined between 1934 and 1952 and a mine on the northern shore of Richardson Lake was operated by M. Kostynuk between 1963 and 1966 (Resident Geologist's Files, Ontario Ministry of Northern Affairs and Mines, Red Lake). There are also several gold showings along the northern and eastern shorelines of Birch Lake. Within the map area, gold has been found just north of Exit Bay (Thurston 1978) and at the portage between Springpole and Birch Lakes (Resident Geologist's Files, Ontario Ministry of Northern Affairs and Mines, Red Lake).

The following is a summary of the characteristics of the gold showings mentioned above. Information was collected from the Resident Geologist's Files, Ontario Ministry of Northern Affairs and Mines, Red Lake, and Horwood (1938).

Most of the showings appear to be in quartz veins controlled by locally developed fault zones. For example, both the Richardson Lake and Argosy deposits occur in quartz veins in fault zones which are oriented east-west and north-south, respectively. Two exceptions to this generalization are the deposit near the portage from Birch Lake to Springpole Lake (discussed below) which occurs in a northwest-southeast trending fault zone only weakly quartz veined, and the deposit examined by Canamer Mining Corporation (Edmond 1966) which occurs in "lensoid breccia fillings and clusters of veinlets.... localized by minor fold structures". Host rocks for these deposits include, in decreasing order of occurrence, metavolcanics (Richardson Lake), wacke or slate (Argosy Mine), diorite dikes (east of Casummit Lake on the old Hewitt-Zigone Claim Group), and iron formation (Canamer Mining Corporation). Most of the studies report silicification ± sericitization ± carbonatization of the wall rock within the fault zones or close to the quartz veins which are associated with the gold mineralization. Associated sulphide mineralization reported in six of the deposits include, in decreasing order of occurrence, pyrite ± arsenopyrite ± pyrrhotite ± chalcopyrite ± sphalerite ± galena. Visible gold was noted in almost all of the deposits.

An interesting gold prospect is located at the portage between Birch and Springpole Lakes. The gold is associated with finely disseminated sulphide mineralization in silicified mafic metavolcanics along a northwest-trending fault zone. Assays reported in 1936 of chip samples from trenches were as high as 2.2 and 1.8 ounces gold per ton across 1.2 and 1.1 m, respectively.

SUGGESTIONS TO PROSPECTORS

Gold deposits in the area have been precipitated from hydrothermal solutions passing through fractured and faulted supracrustal rocks of all types. The prospector should, therefore, concentrate on searching for alteration haloes related to these fluids in the more intensely deformed areas.

In the field, evidence for hydrothermal activity commonly associated with gold deposition have been observed in the following three areas. In the first area, southwest of Graydarl Lake, the mafic metavolcanics (Sequence 1) are commonly enriched in biotite and a fine grained acicular mineral, tentatively identified as tourmaline. This area is also the junction of a northeast-trending basaltic sequence in McNaughton Township (Johns 1979) and the northwest-trending metavolcanics of Sequence 1, however, the structural interpretation here is yet to be determined.

The second area of interest is located in the central part of the map area where abundant quartz-tourmaline veins occur in places associated with quartz-feldspar porphyry intrusions and weak sulphide mineralization.

Finally, about 2500 m north of the central part of Springpole Lake there is an east-west trending chlorite alteration zone within mafic metavolcanics. Associated with this zone is pyrite and magnetite mineralization which has produced a moderately strong magnetic anomaly.

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3. Regional Stratigraphy and Structure of the Lake St. Joseph Area, Central Uchi Subprovince

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INTRODUCTION

This report outlines the results of the second year of a three-year program to upgrade our knowledge of the regional stratigraphy and structure in the central part of the Uchi Subprovince. The region to be described lies in the vicinity of Lake St. Joseph and extends from East Pashkokogan Lake to western Lake St. Joseph. This area is 50 to 85 km south and southwest of Pickle Lake.

The project will continue in 1986 to survey the greenstone belt in the vicinity of Pickle Lake.

Approximately 1500 km^2 were mapped in the Lake St. Joseph area, focusing on bedrock exposures along the lakeshores. Inland from the lakes, the bedrock exposure is poor. This has been a major impediment to gold exploration. Extensive overburden in the area between Soules Bay and the Benmeen Lake pluton, and in the Pashkokogan Lake area has imposed a constraint on the regional correlation of stratigraphy.

This survey presents a revision of previously published maps. It provides a subdivision of the supracrustal stratigraphy into four volcanic cycles in western Lake St. Joseph and shows that the fourth cycle can be traced along the full length of the lake. The northernmost extent of a major dextral shear zone along the southern margin of the belt has been defined. The granitic complex centred on Lake St. Joseph (formerly known as the Carling Granite) has been subdivided into several intrusive and supracrustal units. A summary is presented of the sequence of supracrustal and tectonic events. The eventual objective at the conclusion of this three-year survey is to establish (in conjunction with an associated geochronology program), a regional chronological summary of supracrustal and tectonic events encompassing much of the central Uchi Subprovince.

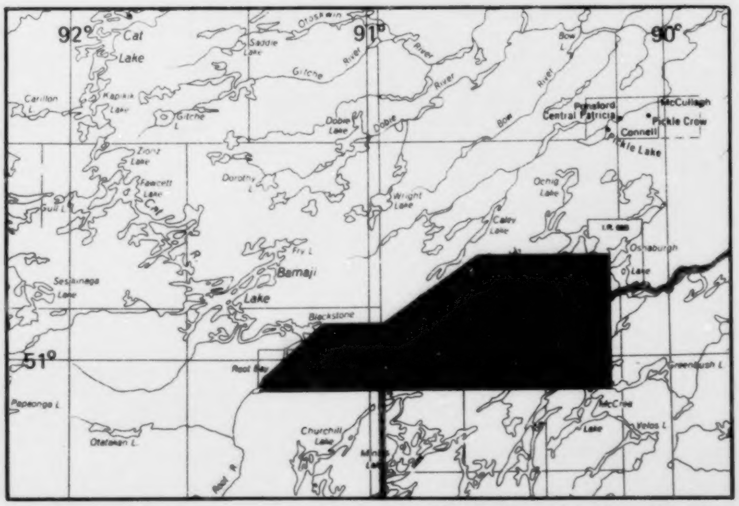
A review of the mineral exploration history, the economic geology of the Lake St. Joseph area and prospecting recommendations for this region are given in an accompanying report in this volume (*see* Kay and Stott).

GENERAL GEOLOGY

Figure 1 summarizes the major stratigraphic units and intrusive bodies in the Lake St. Joseph area. The stratigraphy of the westernmost part of the Lake St. Joseph belt has been subdivided. Four volcanic cycles have been delineated, based on a revision of earlier work by Clifford (1969) and Berger (1981) in western Lake St. Joseph (Figure 2). Berger (1981) introduced formation names which have been adopted to apply to the first three volcanic cycles.

As shown in Figure 2, the three volcanic cycles forming the western Lake St. Joseph stratigraphy are folded about a major east-west-trending anticline that faces eastward, away from the Bamaji-Blackstone batholith. The thickest parts of each cycle, and the most intense carbonatization, occurs in the vicinity of this fold hinge.

Each of the first three cycles comprises a bimodal suite of lower basaltic flows and upper dacitic-rhyolitic pyroclastic deposits. The fourth cycle is also a bimodal assemblage but with a voluminous pyroclastic sequence that typically progresses upward from dacitic to andesitic composition. The extent of the upper, pyroclastic member of the fourth cycle (here termed the Brodribb cycle), as defined by this survey, is shown in Figure 1. There appears overall to be a progressive increase in the volume of total volcanic material from the first cycle to the fourth cycle.


92°
91°
90°
Cat Lake
Saddle Lake
Otoskwin
River
Gitche
Carillon L
Kapikik Lake
Gitche L
Dobie Lake
Dobie
River
Bow L
Bow
River
Pickle Lake
Central Patricia
McCullagh
Pickle Crow
Connell
Zionz Lake
Fawcett Lake
Dorothy L
Gull L
Wright Lake
Ochig Lake
Caley Lake
Osnaburgh
Lake
Fry L
Bamaji
Lake
Sesikinaga Lake
Blackstone
51°
Root Bay
Greenbush L
Papaonga L
Otatakan L
Churchill Lake
McCrea
Lake
Velos L

LOCATION MAP Scale : 1 : 1 548 000 or 1 inch to 25 miles

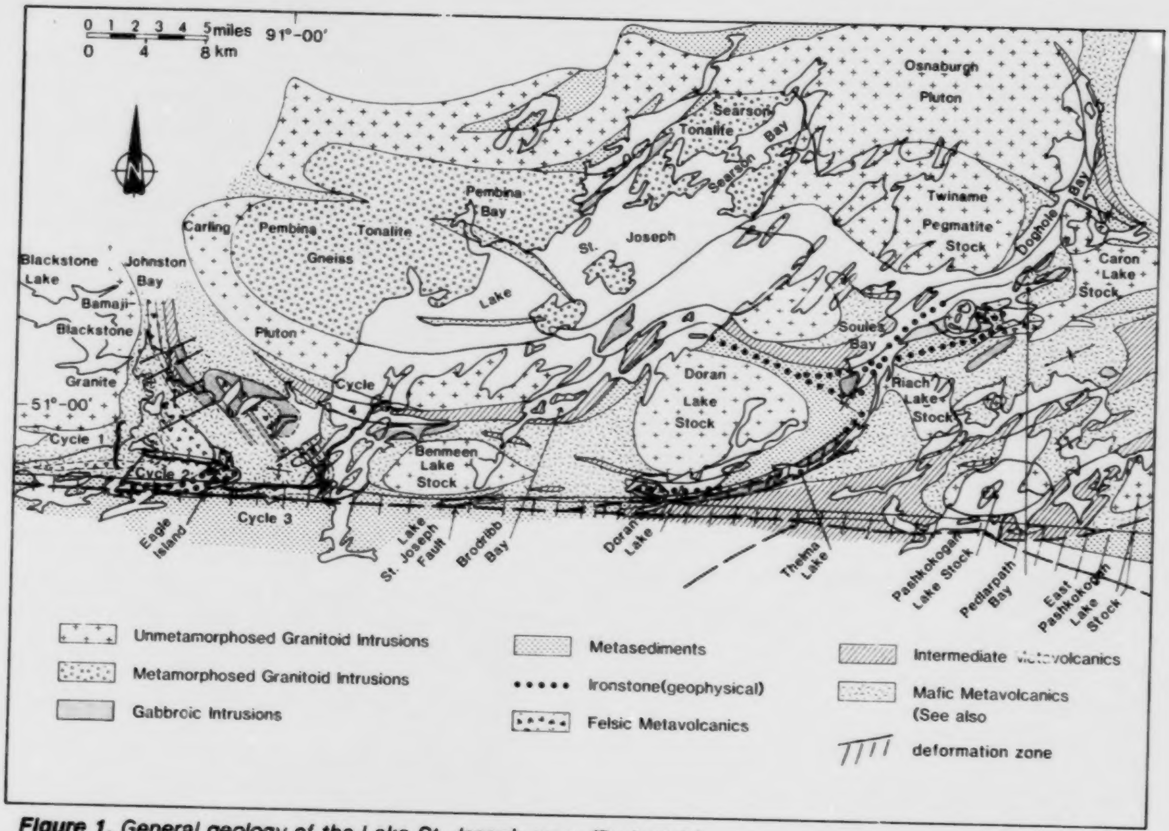

0 1 2 3 4 5 miles
0 4 8 km
91°-00'
51°-00'
Osnaburgh Pluton
Searson Tonalite
Searson Bay
Pembina Bay
St. Joseph
Lake
Twiname Pegmatite Stock
Doghole Bay
Caron Lake Stock
Carling
Pembina Gneiss
Tonalite
Blackstone Lake
Johnston Bay
Bamaji-Blackstone Granite
Pluton
Soules Bay
Doran Lake Stock
Riach Lake Stock
Cycle 1
Cycle 2
Cycle 3
Cycle 4
Benmeen Lake Stock
Eagle Island
Lake St. Joseph Fault
Brodribb Bay
Doran Lake
Thelma Lake
Pashkokogan Lake Stock
Pedlarpath Bay
East Pashkokogan Lake Stock
Unmetamorphosed Granitoid Intrusions
Metamorphosed Granitoid Intrusions
Gabbroic Intrusions
Metasediments
Ironstone(geophysical)
Felsic Metavolcanics
Intermediate Metavolcanics
Mafic Metavolcanics (See also
deformation zone

Figure 1. General geology of the Lake St. Joseph area. (Project 3.)

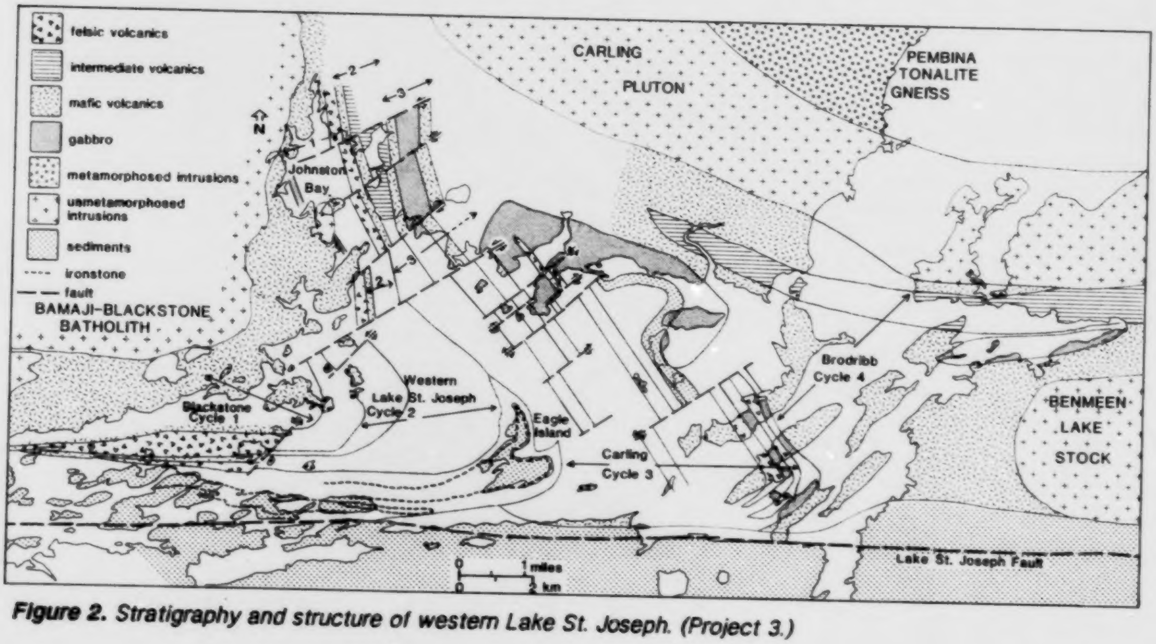

felsic volcanics
intermediate volcanics
mafic volcanics
gabbro
metamorphosed intrusions
unmetamorphosed intrusions
sediments
ironstone
fault
N
BAMAJI-BLACKSTONE BATHOLITH
CARLING PLUTON
PEMBINA TONALITE GNEISS
Johnston Bay
2
3
Blackstone Cycle 1
Western Lake St. Joseph Cycle 2
Eagle Island
Carling Cycle 3
Brodribb Cycle 4
BENMEEN LAKE STOCK
0 1 miles
0 2 km
Lake St. Joseph Fault

Figure 2. Stratigraphy and structure of western Lake St. Joseph. (Project 3.)

The oldest cycle (the Blackstone cycle) forms the westernmost margin of the Lake St. Joseph greenstone belt adjacent to the Bamaji-Blackstone batholith. This cycle is divided into a lower basaltic assemblage and an upper dacitic to rhyolitic assemblage. Individual flows in the lower half of the basaltic suite show a progression from massive to pillowed phases with only local evidence of carbonate alteration in the pillowed units. However, upwards through this basaltic stratigraphy along the major anticlinal hinge line, there is an increase in the presence of very fine iron carbonate amygdules. This has produced an intensely pitted weathered surface which, along with locally abundant iron carbonate-quartz veins, characterizes the hinge zone of this anticline.

The upper rhyolitic-rhyodacitic member of the Blackstone cycle comprises several pyroclastic units. Deposits have been observed that are typical of a depositional environment proximal to a volcanic vent. These occur in the hinge zone of the anticline and locally on its southern limb. Such deposits include clast-supported flow breccias, and pyroclastic flows with coarse lithic clasts and rounded clasts of massive sulphide mineralization. Abundant, typically carbonatized basaltic dikes transect the stratigraphy in the anticlinal hinge zone. In this zone, the pyroclastics are also pervasively iron carbonatized.

The West Lake St. Joseph (WLSJ) cycle overlies the Blackstone cycle and is dominated by its felsic pyroclastic member. The underlying, comparatively thin (<0.5 km) basaltic member of the WLSJ cycle is intensely iron-carbonatized. The corresponding pervasive white weathering of the basalts increases in intensity eastward through the stratigraphy in the hinge zone of the anticline. In this vicinity, there are also pods and veins of quartz and iron carbonate + quartz with stringers of pyrite in the carbonate. The quartz forms narrow "ladder" fracture fillings in the massive carbonate pods. The presence of basaltic dikes and local diatreme breccia dikes attest to the pro8imity of a volcanic vent in the same vicinity.

Further evidence of a vent facies assemblage is found in the overlying rhyolitic member of the WLSJ cycle. The base of the rhyolitic suite on the anticlinal hinge is marked by a massive quartz-feldspar-phyric flow which progresses stratigraphically upward into a phreatic breccia of angular to subrounded clasts. Overlying this are a series of pyroclastic flow deposits. Clast sizes diminish along the limbs of the anticline. In Johnston Bay, the upper member of the WLSJ cycle is dominated by dacitic to andesitic tuff and associated volcaniclastic sediments.

These first two volcanic cycles, west of Eagle Island, may have had a common vent system. The vent and proximal facies deposits are concentrated in the hinge zone of the large anticline which marks the position of the common edifice for the two cycles. Substantial erosion of at least the top of the WLSJ cycle is inferred from the presence in Johnston Bay of dacitic to andesitic tuffaceous rocks on the flanks of this edifice. Andesitic tuff is dominant. Epiclastic sedimentary interlayers occur locally with hornblende-rich calc-silicate ironstone horizons.

The overlying Carling cycle lies east and north of Eagle Island. Available younging directions indicate that this volcanic assemblage faces eastward and outlines the same large anticline that folds the first two cycles. The Carling cycle is dominated by massive to pillowed basaltic flows. The overlying rhyolitic to rhyodacitic pyroclastics have been intruded by thick gabbroic sills. Coarse rhyolitic flow breccia underlying a thick tuffaceous sequence is found near the hinge of the anticline. Thinly bedded clastic metasediments overlie the pyroclastic member along the northern limb of the fold and appear to mark the top of the Carling cycle. As shown in Figure 1, a set of major transcurrent faults has offset the local stratigraphy along the northern limb of the anticline.

The Brodribb cycle is the fourth and most extensive volcanic cycle identified in this survey. Poor bedrock exposures inland between Doran Lake and western Lake St. Joseph prevent clear recognition of the base of this cycle. However, the upper pyroclastic member of the Brodribb cycle is traceable eastward from north of western Lake St. Joseph to Soules Bay in the eastern part of the lake. A possible farther extension of this sequence along the eastern margin of Doghole Bay is being evaluated.

The pyroclastic sequence of the Brodribb cycle is typified by an upward progression towards the north from dacitic lithic tuff-breccia to highly vesicular tuff-breccia to an increasingly mafic-rich dacitic to andesitic lapilli-tuff. The coarsest pyroclastic deposits are to be found north and northeast of Soules Bay. Farther west, the sequence is represented by a tuffaceous assemblage which displays characteristic progression northwards from dacitic tuff to andesitic tuff with locally abundant mafic lapilli clasts. This compositional change through the pyroclastic suite is consistent with a major eruption from a compositionally zoned magma chamber.

The Brodribb cycle is overlain by basaltic rocks exposed along the southern margin of the Lake St. Joseph granitoid complex. The basalt may be the base of a fifth volcanic cycle.

The inter-relationships among the major stratigraphic components in the Pashkokogan Lake area and in the area south and west of Doran Lake have not yet been successfully resolved. The intermediate volcanic rocks that outline a large fold on Pashkokogan Lake are similar to the dacitic to andesitic tuffs of the Brodribb volcanic cycle.

Major metasedimentary suites were originally mapped by Goodwin (1965) and Clifford (1969) and only modest revisions have been made to the original mapping of these units during this survey.

A major anticline plunging steeply to the east lies along the central axis of the Soules Bay metasedimentary suite. The metasediments thus stratigraphically underlie the uppermost part of the Brodribb volcanic cycle. This assemblage of sediments is composed of staurolite- and locally andalusite-bearing metawacke interbedded with magnetite ironstone. Garnet is concentrated at the metawacke-ironstone interface in most places, where iron was scavenged from the adjacent ironstone beds during prograde metamorphism. This sedimentary suite widens to the west and partly wraps around the post-tectonic Doran Lake stock.

A synclinally folded suite of wacke and local sillimanite-bearing metapelites lies southeast of Doghole Bay. These rocks appear to overlie the westward-facing pyroclastics and interbedded volcaniclastic sediments on the eastern side of Doghole Bay. They may be related to the large enclaves of metasediments found within and along the northern margins of the Osnaburgh pluton. These enclaves have been interpreted to correlate with the Billett Lake-Teevin Lake metasediments (Stott and Wallace 1984) which unconformably overlie the southward-facing volcanic cycles in the Meen Lake-Kasagiminnis Lake belt to the north.

In western Lake St. Joseph, a folded sequence of magnetite ironstone and clastic metasediments infills a major basin along the southern margin of the volcanic belt. These sediments, best exposed on Eagle Island and a chain of islands to the west, were deposited unconformably within a basin that was carved out subsequent to both the deposition of the first three volcanic cycles described above and an eastward tilting of the volcanic stratigraphy. The sediments form a basal suite of volcaniclastic material derived mainly from the felsic volcanic rocks of the upper WLSJ cycle (Berger 1981). This was followed by a largely quiescent period during which much of the ironstone was deposited with intervening wacke beds. This stage was blanketed by the development of a major submarine fan deposit (Meyn and Palonen 1980) that prograded southward away from the volcanic pile. There is evidence that a major proportion of this epiclastic suite was derived from a felsic source, most likely from the felsic volcanic rocks that dominate the stratigraphy immediately north of these metasediments. The Lake St. Joseph Fault separates these rocks from higher grade biotite-bearing metawacke to the south in the English River Subprovince.

Thick gabbroic sills and substratiform dikes have injected the upper part of the Carling volcanic cycle, parts of the Brodribb cycle, and the Soules Bay metasediments. A large tabular gabbroic intrusion is interpreted to underlie part of central Lake St. Joseph. Numerous gabbroic islands northeast of Brodribb Bay outline this large intrusion. A modest degree of compositional zoning is observed locally on the largest gabbroic island north of Brodribb Bay.

A differentiated sill of peridotite to gabbro and local granophyre is intruded into the Carling volcanic cycle in western Lake St. Joseph. A large gabbroic intrusion and several sills occur in proximity to this differentiated sill and may constitute a concomitant suite.

Likewise, there are long tabular gabbroic sheets which have intruded the margin of the Soules Bay metasediments. One of these intrusions is mylonitized and trends along the southern shore of Doran Lake and into Thelma Lake.

On the peninsula north of Pedlarpath Bay in eastern Lake St. Joseph, three mafic intrusions have been mapped, two of which contain an outer peridotite margin exposed along the shoreline.

All gabbroic intrusions acquired a tectonic fabric that corresponds to the regional strain fabric in the enclosing supracrustal rocks. Two small exposures of a westward-trending Proterozoic diabase dike were identified northeast of Brodribb Bay. One of these was previously mapped by Goodwin (1965).

The granitoid rocks in this area are dominated by late- to post-tectonic plutons. No synvolcanic stocks were identified. All granitic intrusions within the supracrustal rocks contain primary unmetamorphosed fabrics and some impose a very narrow contact strain aureole. These late plutons including the Bamaji-Blackstone batholith, Benmeen Lake stock, and the stocks on Pashkokogan Lake, are typically composed of quartz-phyric granodiorite to monzogranite. The quartz phenocrysts define a very steep primary lineation which contrasts with the regional stretching lineation of the tectonic fabric in the surrounding greenstone belt. The Bamaji-Blackstone batholith is a large intrusion which imposed a 1.5 km wide contact strain aureole upon the Blackstone basalts along its eastern margin.

The Doran Lake stock is a post-tectonic potassium feldspar megacrystic granite to syenite that has intruded into a pre-existing anticline that trends through Soules Bay.

The Lake St. Joseph granitoid complex has been subdivided in this survey as shown in Figure 1. It is composed of an older tonalite to tonalite gneiss terrain which was subsequently intruded by post-tectonic granodiorite to monzogranite plutons. These younger bodies appear to have injected along a pre-existing interface between an older tonalitic terrain and the surrounding greenstone belt. The result has produced large sheet-like intrusions such as the crescent-shaped Carling pluton and the Osnaburgh pluton. Dominant parts of these late intrusions are potassium feldspar megacrystic, and major granitic dikes have injected from these bodies into the adjacent older tonalite.

The Osnaburgh pluton imposed a 2 km wide contact strain aureole upon the greenstone belt to the north of the body.

The older tonalite terrain is subdivided into two parts. One is best exposed along Searson Bay and is referred to as the Searson Tonalite. This fine grained tonalite mass is partly bordered on the northwest by a large enclave of clastic metasediment. The margins are heavily intruded by granite dikes from the adjacent Osnaburgh pluton and Twiname Pegmatite stock.

Of particular note is the Twiname Pegmatite stock in Eastern Lake St. Joseph. This body is approximately 8 to 12 km in diameter and is composed of coarse tourmaline-bearing muscovite granite pegmatite with garnetiferous aplitic granite dikes. The surrounding granitic rocks have been intruded by muscovite, garnet-bearing pegmatite dikes from this body. There is also an abundance of muscovite pegmatite dikes in the supracrustal rocks to the east and south of the Twiname Pegmatite stock. A smaller muscovite pegmatite stock occurs at the northern tip of the Caron Lake stock. In view of the presence of lithium-bearing pegmatite dikes on East Pashkokogan Lake, the recognition of this pegmatite field may warrant an evaluation of its rare element potential (*see* Kay and Stott, this volume).

The other tonalite terrain is the domical shaped Pembina tonalite gneiss. This area is pervaded by abundant granitic dikes and foliation-parallel interlayers. This gneissic terrain is partly separated from the more homogeneous Searson tonalite by a thin discontinuous band of amphibolite. This amphibolite is only locally exposed near Pembina Bay; near Carling Island it forms abundant tabular inclusions in tonalite.

STRUCTURAL GEOLOGY

Two major anticlines are clearly defined. The western Lake St. Joseph stratigraphy is folded by a large eastward-facing anticline. Another anticline exposes the Soules Bay metasediments which underlie the Brodribb volcanic cycle.

Large folds of the stratigraphy in the Pashkokogan Lake area are evident from the map pattern but reliable younging directions in that area have not been clearly established.

Along the length of the greenstone belt, regional fold axes and lineations generally plunge steeply eastward or down dip of the foliation. Bedding and foliation generally dip steeply throughout the belt.

The regional deformation and metamorphism was followed by the emplacement of the late granitic plutons. Near the Bamaji-Blackstone batholith, the regional foliation and lineation in the supracrustal rocks is rotated to conform with the strain fabric within the contact strain aureole around the batholith.

This batholith appears to predate a regional deformation event that developed within the adjacent English River Subprovince and affected the southern margin of the greenstone belt. This event has resulted in a subhorizontal shortening and dextral transcurrent shearing along a broad front from near the boundary between the Uchi and English River Subprovinces. Transcurrent shearing of rocks can be traced northward 1.3 km into the greenstone belt from the Lake St. Joseph Fault that marks the subprovince boundary. Structural features show consistent evidence of dextral transcurrent shear. These include Z-folds, shear bands, sygmoidal asymmetry in the compositionally layered rocks, plus subhorizontal mineral lineations and associated steeply plunging crenulations. Local kink bands in these sheared metasediments are interpreted as a brittle product of this event.

This fault system has been observed from the sheared southern part of the Bamaji-Blackstone batholith eastward to the southern margin of Pashkokogan Lake. A fault splaying off the main fault trends along the southern margin of Doran Lake into Thelma Lake where a sill-like gabbroic intrusion is mylonitized.

Evidence in the western Lake St. Joseph area indicates that prior to the folding that resulted from a regional north-south compression, a stage of tectonic uplift occurred. The structural relationships in the vicinity of Eagle Island are critical to this interpretation. The available evidence of younging directions in the stratigraphy (Berger 1981; Meyn and Palonen 1980) demonstrates that the Eagle Island metasedimentary suite formed a synclinal basin. However, this basin lies unconformally upon an eastward-facing volcanic pile. Subsequently, the three volcanic cycles in the area plus the Eagle Island metasediments were deformed by a north-south compression. This accentuated the volcanic edifice into an eastward-facing anticline and tightened and refolded the synclinal sedimentary basin around the nose of this anticline.

The general setting of the western Lake St. Joseph area is comparable to the Geraldton area in that it contains folded ironstone units in a metasedimentary belt along the margins of a greenstone belt with a major transcurrent shear zone along the subprovince boundary. The major dextral transcurrent shear zone, defined along the southern part of the lake, affects the southern edge of Eagle Island and much of the interbedded and Z-folded ironstone and wacke deposits to the west of the island. The rocks in this shear zone accordingly have undergone two periods of deformation.

The overall tectonic history involves a general sequence of:

1. Regional tilting of the stratigraphy in western Lake St. Joseph.
2. Erosion of the volcanic pile to produce the Eagle Island ironstone-lined basin and submarine fan deposits. The relative age relationship has not been established between these sediments and the sediments of the English River Subprovince south of the Lake St. Joseph Fault.
3. Regional north-south compression that produced the major folds and the penetrative foliation. This event may be related to or concomitant with the emplacement of the tonalite of the Lake St. Joseph granitoid complex.
4. Emplacement of the granitoid plutons and stocks (Bamaji-Blackstone batholith, Carling pluton, etc.).
5. Regional oblique compression along a northwest-southeast axis to produce a major dextral transcurrent shear zone along the southern margin of the greenstone belt and into the English River Subprovince. The emplacement of some granite stocks may be concomitant with or postdate this event.

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4. Reconnaissance Evaluation of the Wunnummin Lake Belt

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INTRODUCTION

A two-day reconnaissance was conducted in the Wunnummin Lake belt, located approximately 225 km north of Pickle Lake. The area examined is show in Figure 1, which is taken from Prest (1942) with modest revisions and additions.

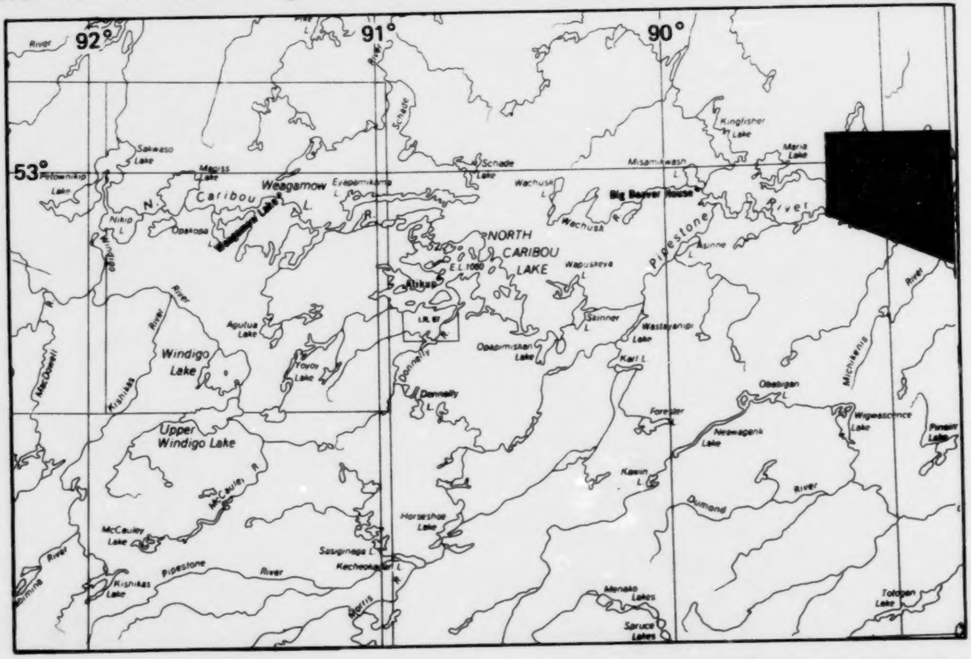
This narrow, approximately 7 km wide, belt of supracrustal rocks appears to form a simple easterly-plunging syncline of massive to pillowed metabasalts overlain dominantly by clastic metasediments.

The southern half of the belt is characterized by a Z-folded stratigraphy with a consistent northward facing direction based on younging criteria such as graded bedding in the metasediments and pillow packing in the basalts. The bedding across the belt dips steeply to the south. There is a contrast in the relative orientation of bedding and cleavage between the northern and southern limbs of the belt which, in view of other evidence, is consistent with an easterly-plunging syncline along the central axis of the belt. Z-folds occur in the southern half of the belt and rare S-folds in the northern half. These observations plus available younging evidence, support Prest's (1942) original interpretation that the belt forms a major syncline.

Mineral lineations and stretched clasts in conglomerate beds plunge eastward and parallel the axes of local folds. The overall facing direction of the stratigraphy, based on the above structural evidence, is to the east.

A major dextral transcurrent shear zone, approximately 3 km wide, lies within the granodiorite to tonalite intrusion along the northern margin of the greenstone belt. Available aeromagnetic maps (ODM-GSC 1963) suggest that this shear zone extends at least as far as the Big Trout Lake belt north-northwest of Wunnummin Lake. Further evidence that this shear zone continues along the northern margin of the belt southeast of Wunnummin Lake is found locally. The shear zone has not been previously documented although brief reference to mylonite zones was made by Thurston *et al.* (1979, p.95). The zone shows clear evidence of a right-handed sense of shear with a shallowly-eastward plunging movement direction. The evidence comprises sygmoidal quartz ribbons, shear bands, and dextrally-rotated feldspar porphyroclasts in a mylonitic matrix. The northernmost part of the greenstone belt is moderately affected but the main zone of shear is limited to the adjacent tonalitic batholith. The most intense deformation is found close to the greenstone belt margin with the intensity decreasing northward away from the belt. This shear zone has limited interaction with the greenstone belt and does not appear to be significant for gold exploration.

The large peninsula on Wunnummin Lake, east of Chiah Lake contains two units of interest. A tremolite-


92°
91°
90°
53°
River
Sakwaso Lake
Pelownikip Lake
Magiss Lake
Caribou
N.
Weagamow L.
Weagamow Lake
Eyapamikama L.
R.
Nikip L.
Opakopa L.
Schade
Schade Lake
Wachusk L.
Wachusk
Misamikwash L.
Big Beaver House
Kingfisher Lake
Maria Lake
Pipestone
River
NORTH CARIBOU LAKE
E.L.1000
Wapuskeya L.
Asinne L.
Agutua Lake
Windigo Lake
Yoyoy Lake
Donnelly
Donnelly L.
Opapimiskan Lake
Skinner L.
Wastayanipi Lake
Karl L.
MacDowell
Kishikas
Upper Windigo Lake
McCauley R.
McCauley Lake
Kishikas Lake
Pipestone
Horseshoe Lake
Sasiginaga L.
Kecheokagan L.
Forester L.
Obabigan L.
Neawagank Lake
Wigwascence Lake
Michikenis
Kawin L.
Dumond
River
Menako Lakes
Spruce Lakes
Totogan Lake
Pennair Lake

LOCATION MAP

Scale : 1 : 1 548 000 or 1 inch to 25 miles

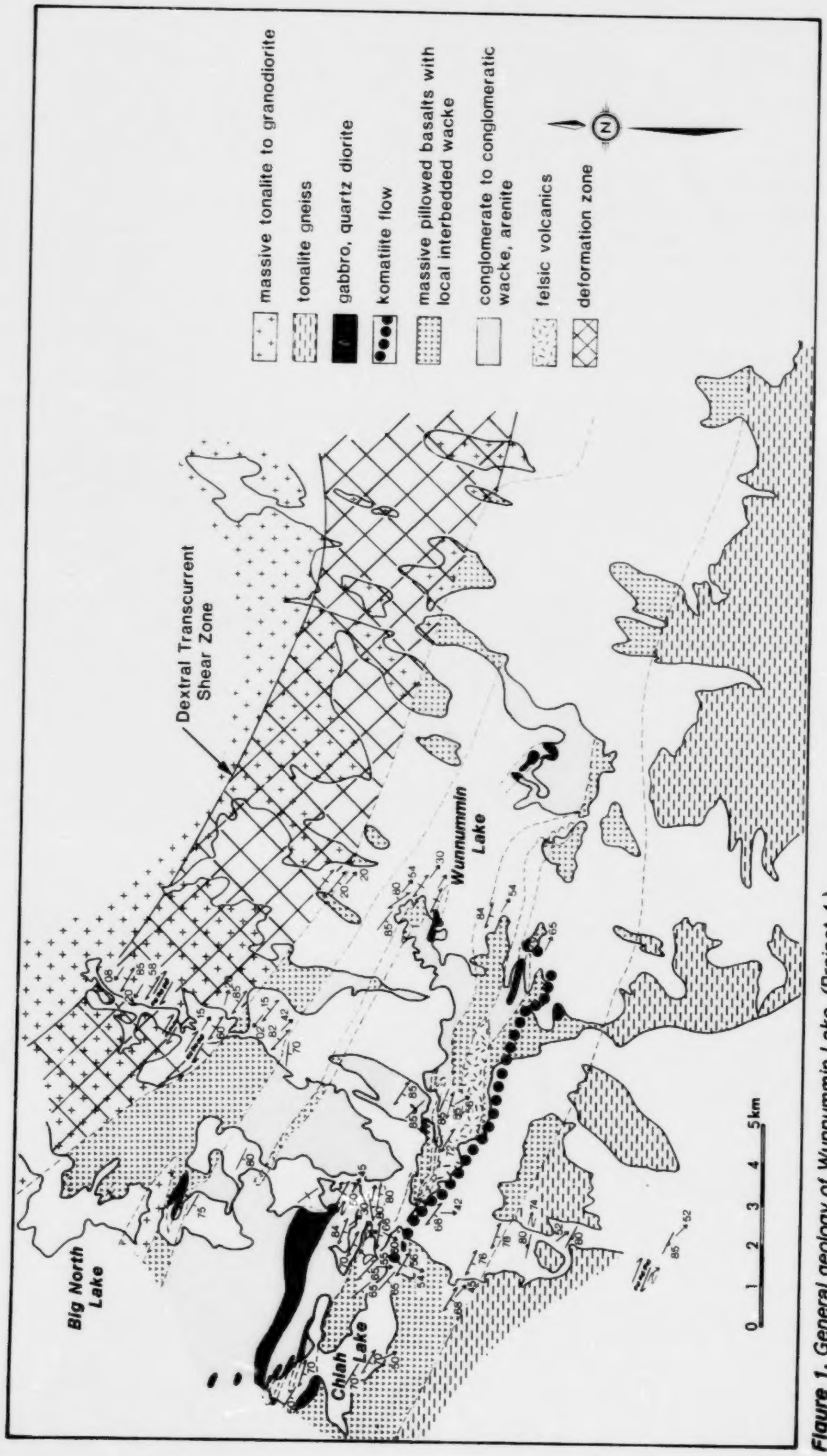

massive tonalite to granodiorite
tonalite gneiss
gabbro, quartz diorite
komatiite flow
massive pillowed basalts with local interbedded wacke
conglomerate to conglomeratic wacke, arenite
felsic volcanics
deformation zone
N
Dextral Transcurrent Shear Zone
Wunnummin Lake
Big North Lake
Chiah Lake
0 1 2 3 4 5km

Figure 1. General geology of Wunnummin Lake. (Project 4.)

rich ultramafic flow, locally observed to be 20 m wide, forms a distinctive marker unit several kilometres long within the southern limb of the belt. Stratigraphically above this is a lensic unit described by Prest (1942) as an intrusive felsite and interpreted here to be a very fine grained rhyolitic flow. Overlying this unit and infolded within basalts, are wacke to arenite beds that were formerly mapped as a "highly schistose grey granite dike" in the irregular bay at the northern end of the Wunnummin peninsula (Prest 1942, p.16).

The metasediments along the central axis of the Wunnummin Lake belt are dominated by wacke matrix-supported conglomerate beds containing rounded boulders and cobbles of medium grained tonalite and less abundant clasts of other rock types (Prest 1942; Thurston *et al.* 1979).

The large area of migmatized metasediments previously interpreted by Thurston *et al.* (1979, Map 2292) to envelope the belt is reinterpreted as tonalite. The northern migmatized metasediments are mylonitized tonalite and the southern area of such rocks on Map 2292 is a tonalite gneiss.

The authors observations indicate very little evidence for primary or tectonic hydrothermal alteration of the volcanic rocks. The rocks are moderately deformed with evidence of shearing observed only locally in the northern part of the belt.

ECONOMIC GEOLOGY

There is little exploration work known to have been carried out in the Wunnummin Lake belt. Most previous work focused on geophysically located targets for base metals. The present reconnaissance study failed to find any new prospects but derived the following conclusions:

1. No sign of mineralization or quartz veining was noted in the large mylonite zone along the northern margin of the belt. Economic prospects there are considered poor.
2. The lean oxide facies ironstone reported by Thurston *et al.* (1979) was not seen. Analyses reported previously (Thurston *et al.* 1979) suggested a low possibility of economic gold mineralization in this unit.
3. A local muscovite-quartz alteration zone containing pyrite lenses occurs in or near the southern contact of the massive dacite to rhyolite unit on the Wunnummin peninsula. There may be some possibility of base metal mineralization associated with this feature.
4. During the field work, very few quartz veins were noted in any rocks. Those observed contained no significant sulphide mineralization. The possibility of discovering quartz-gold veins appears to be low.

In summary, initially this reconnaissance was based on the premise that the geology of the Wunnummin Lake belt might be similar to the North Caribou Lake belt. However, there does not appear to be a great similarity between the belts with respect to the structure or stratigraphy. An exploration model useful in the North Caribou Lake belt would not be suitable for Wunnummin Lake.

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5. Economic Geology of the Lake St. Joseph Area

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INTRODUCTION

In addition to regional mapping around Lake St. Joseph (*see* Stott, this volume), a preliminary evaluation was made of the economic geology of the area. Partial funding for this aspect of the project was provided by D. Janes, Resident Geologist, Ontario Ministry of Northern Affairs and Mines, Sioux Lookout. Work performed consisted of:

1. a summary of assessment data filed to date,
2. detailed mapping (1:100) of reported mineral occurrences, and
3. prospecting in conjunction with the regional mapping.

PREVIOUS WORK

The Lake St. Joseph greenstone belt has largely been the focus of iron ore exploration. As a result, much of the assessment data available pertains to iron ore targets. Unless otherwise stated, all data are from the Assessment Files Research Office, Ontario Geological Survey, Toronto.

In the late 1950s, three extensive iron ore deposits were outlined in the Soules Bay, Doran Lake, and Eagle Island areas. Reserves totaling some 1.2 million tons, averaging 19% to 35% Fe were defined by Sanjo Iron Mines Limited (Soules Bay), Little Long Lac Gold Mines Limited (Doran Lake), and Lake St. Joseph Iron Limited (Eagle Island). These deposits are currently covered by patented claims and are shown on Figure 1. The few active claims in the area are also shown on this figure.

More recent exploration of the belt has been sporadic and principally directed towards massive sulphide deposits. A summary of this, and the above-mentioned work, is given in Table 1.

As is evident from Table 1, relatively little assessment data pertaining to gold exploration has been filed. A major objective of mapping, therefore, was to determine the potential for significant gold mineralization in the Lake St. Joseph area.

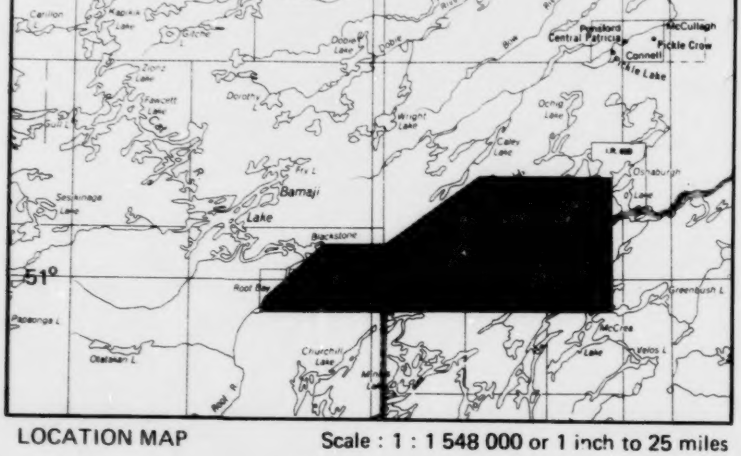
A second feature of economic interest was the rare element potential of the abundant pegmatite dikes reported along the Uchi-English River Subprovinces boundary.

GOLD

With the exception of the above-mentioned iron ore deposits, relatively few mineral occurrences of economic interest have previously been defined in the Lake St. Joseph greenstone belt. During the current regional mapping program, an attempt was therefore made to assess the potential for such mineralization with particular emphasis on gold. The eastern end of the belt was examined in reconnaissance fashion with the focus on the limited lakeshore exposures along Doghole Bay, Soules Bay, and Brodribb Bay. Bedrock is poorly exposed inland, making detailed evaluation of the mineralization potential difficult. The western end of the greenstone belt is marked by excellent lakeshore exposures and was studied in much greater detail. The nature and presence/absence of veining, alteration, and mineralization was documented throughout the belt, and is discussed below.

VEINING

For our purposes, the eastern part of the Lake St. Joseph greenstone belt is defined as extending from East Pashkokogan Lake to Brodribb Bay on Lake St. Joseph. This area is largely characterized by narrow (typically <15 cm), undeformed bull quartz veins which are usually subparallel with or at a low angle to foliation. Locally, minor tourmaline and less commonly visible sulphide mineralization was noted in these veins, but grab samples returned low gold values. Unless otherwise stated, all assay samples



LOCATION MAP

Scale : 1 : 1 548 000 or 1 inch to 25 miles

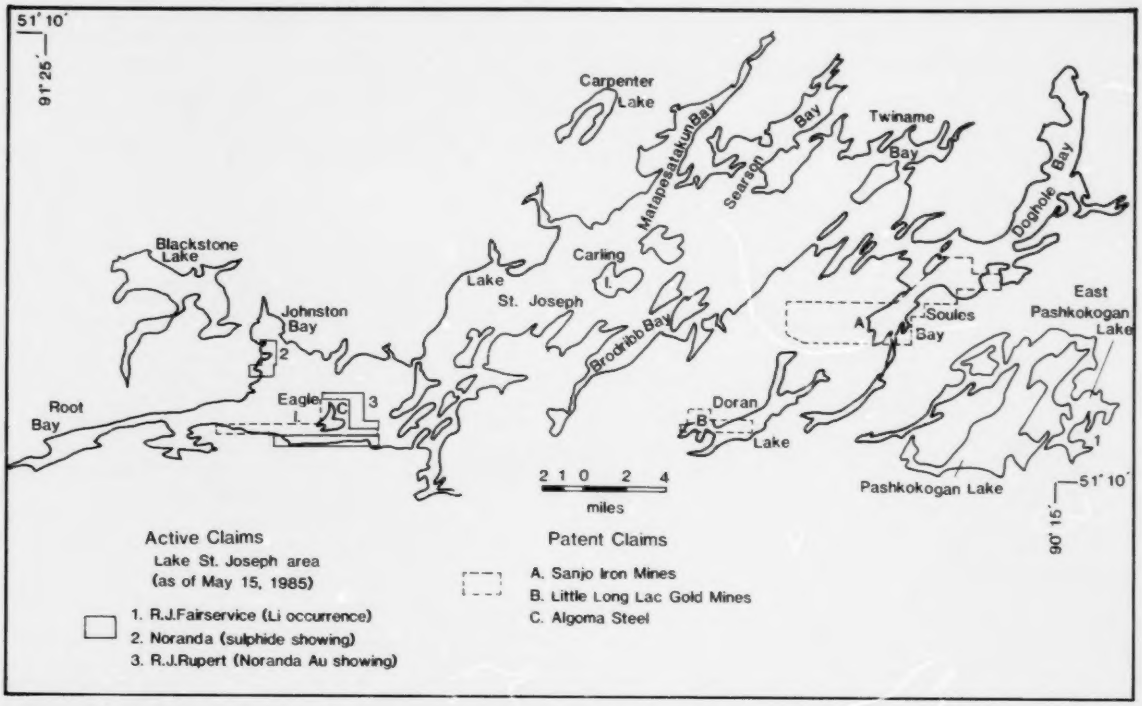

51° 10'
91° 25'
Carpenter Lake
Matapesatakun Bay
Searson Bay
Twiname Bay
Doghole Bay
Blackstone Lake
Carling L.
Lake St. Joseph
Johnston Bay
Brodribb Bay
East Pashkokogan Lake
Soules Bay
A
2
Root Bay
Eagle I.
C
3
Doran Lake
B
1
2 1 0 2 4
miles
Pashkokogan Lake
51° 10'
90° 15'
Active Claims
Lake St. Joseph area
(as of May 15, 1985)
1. R.J.Fairservice (Li occurrence)
2. Noranda (sulphide showing)
3. R.J.Rupert (Noranda Au showing)
Patent Claims
A. Sanjo Iron Mines
B. Little Long Lac Gold Mines
C. Algoma Steel

Figure 1. *Location of both active and patented claims in the Lake St. Joseph area (May 1985). (Project 5.)*

discussed herein were collected by field party personnel and analyzed by the Geoscience Laboratories, Ontario Geological Survey, Toronto.

The relative abundance of quartz veining varies throughout this part of the belt. The veins are very prominent within the sediments in Soules Bay and the gabbroic intrusion northeast of Soules Bay.

Minor rusty weathering, foliation-parallel iron-carbonate stringers were seen locally in the mafic volcanic rocks along the southern shore of Pedlarpath Bay. These are generally narrow (<5 cm) and contain no visible sulphide mineralization.

Veining throughout the western part of the belt (i.e. west of Brodribb Bay) was noted in three distinct forms:

1. quartz ± tourmaline veins, subparallel with or at a low angle to foliation (Type 1);
2. massive iron-carbonate pods and veins, and narrower veinlets, generally parallel with foliation (Type 2); and
3. foliation-parallel, metamorphically differentiated quartz ± plagioclase veins (Type 3).

Each of these three vein types appears to occur in the absence of other vein types. They characterize the following areas:

Type 1: These quartz ± tourmaline veins were noted in the bay northwest of the Benmeen Lake area, south of Brodribb Bay, and in the gabbroic intrusion north of Eagle Island. South of Brodribb Bay the veins occur in a well-defined regional set obliquely crosscutting the foliation.

Type 2: Iron carbonate ± quartz pods, veins, and veinlets characterize the mafic volcanic rocks east of the Bamaji-Blackstone batholith. The carbonate contains local stringers of pyrite. The veins are notably abundant on the islands west of Eagle Island.

Type 3: Metamorphically differentiated foliation-parallel quartz ± plagioclase veins are restricted to the shear zone along the Uchi-English River Subprovince boundary. These veins are observed within the intensely deformed metasediments north and south of the Lake St. Joseph Fault.

Of the three vein types, the most notable are massive iron-carbonate pods and veins. These are most prominently developed in the basalts of the West Lake St. Joseph volcanic cycle near the hinge zone of the large anticline that folds the stratigraphy in the western part of the belt. These hydrothermal deposits occur within highly carbonatized pillowed basalts. They are generally subparallel to the regional east-west-trending foliation and occupy interpillow spaces. Some of the larger lensic pods contain ladder quartz veins and fine grained stringer pyrite.

Carbonate-quartz veins are not entirely restricted to the hinge zone of the anticline. They are also observed in places along the northern and southern limbs of this fold.

ALTERATION

In general, there is a spatial association between the pervasive carbonatization of the volcanic rocks in western Lake St. Joseph, which is interpreted to be a primary hydrothermal alteration, and the foliation-par-

TABLE 1. SUMMARY OF ASSESSMENT DATA (MAY 1985). (PROJECT 5.)

Area (by claim map and NTS)	Type of Work (see below for key)					
	1	2	3a	3b	4	5
Greenbush Lake (52J/16NE)	4 400 ft	gf, py	4	-	Li peg	GDIF 218
Pashkokogan Lake (52J/16NW)	20 4900 ft	py, cpy po, gf, mag	5	1	-	GDIF 217
Doran Lake (52J/15NE)	7 2911 ft	py, po cpy, mag	2	-	-	work concentrated on Fe formation
Dawson Lake (52J/15NW)	4 1382 ft	py, po gf	1	-	-	
Trist Lake (52J/14NE)	56 20 700 ft	py, po cpy, au	5	-	Au	Au showing reported by Noranda on island 17; work concentrated on Fe formation
Caron Lake (52O/01SE)	11 2859 ft	py, po cpy, gf	5	-	-	GDIF 214
Riach Lake (52O/01SW)	81 36 436 ft	-	6	-	-	GDIF 213 work concentrated on Fe formation
Carling Island (52O/02SE)	30 11 295 ft	-	4	-	-	work concentrated on Fe formation
Pembina River (52O/02SW)	-	-	1	-	-	
Johnston Bay (52O/03SE)	12 1624 ft	py, po cpy	3	1	-	

Key:
1. Diamond Drilling; number of holes/total footage
2. Mineralization encountered in drill holes (py-pyrite, cpy-chalcopyrite, gf-graphite, po-pyrrhotite, mag-magnetite, au-gold).
3. Geophysical surveys (number of surveys performed): (a) ground geophysics, (b) airborne geophysics.
4. Mineral occurrences (known).
5. General comments and availability of GDIF (Geological Data Inventory Folios compiled by Resident Geologist's Office in Sioux Lookout).

allel carbonate veins. The latter are interpreted to be syntectonic hydrothermal deposits perhaps a recirculation of material from the host rock. These two hydrothermal events, one primary, the other related to the regional deformation, are accompanied by a third event along the southern limb of the anticline. There, a further cycling of hydrothermal fluids occurred within a ductile shear zone. Within the metasediments, these resulting foliation-parallel veins are typically composed of quartz or quartz + feldspar with local tourmaline. There is little evidence of associated sulphide mineralization.

In other parts of the greenstone belt farther east, there was little evidence of alteration of the volcanic rocks.

MINERALIZATION

As previously mentioned, few mineral occurrences of economic interest have been recorded in the Lake St. Joseph greenstone belt. Noranda Incorporated reports a chemical sediment-hosted gold showing east of Eagle Island. This, along with a sulphide occurrence at the mouth of Johnston Bay, constitutes the only active claim group within the Lake St. Joseph area (*see* Figure 2).

The majority of the sulphide occurrences on the 1 inch to 4 mile compilation geology map consist of numerous geophysical conductors which have been tested by drilling, and are now documented in the assessment files (Table 1).

At the eastern end of the lake, few new mineral occurrences were noted during the course of the present survey. Two small, chert-hosted massive sul-

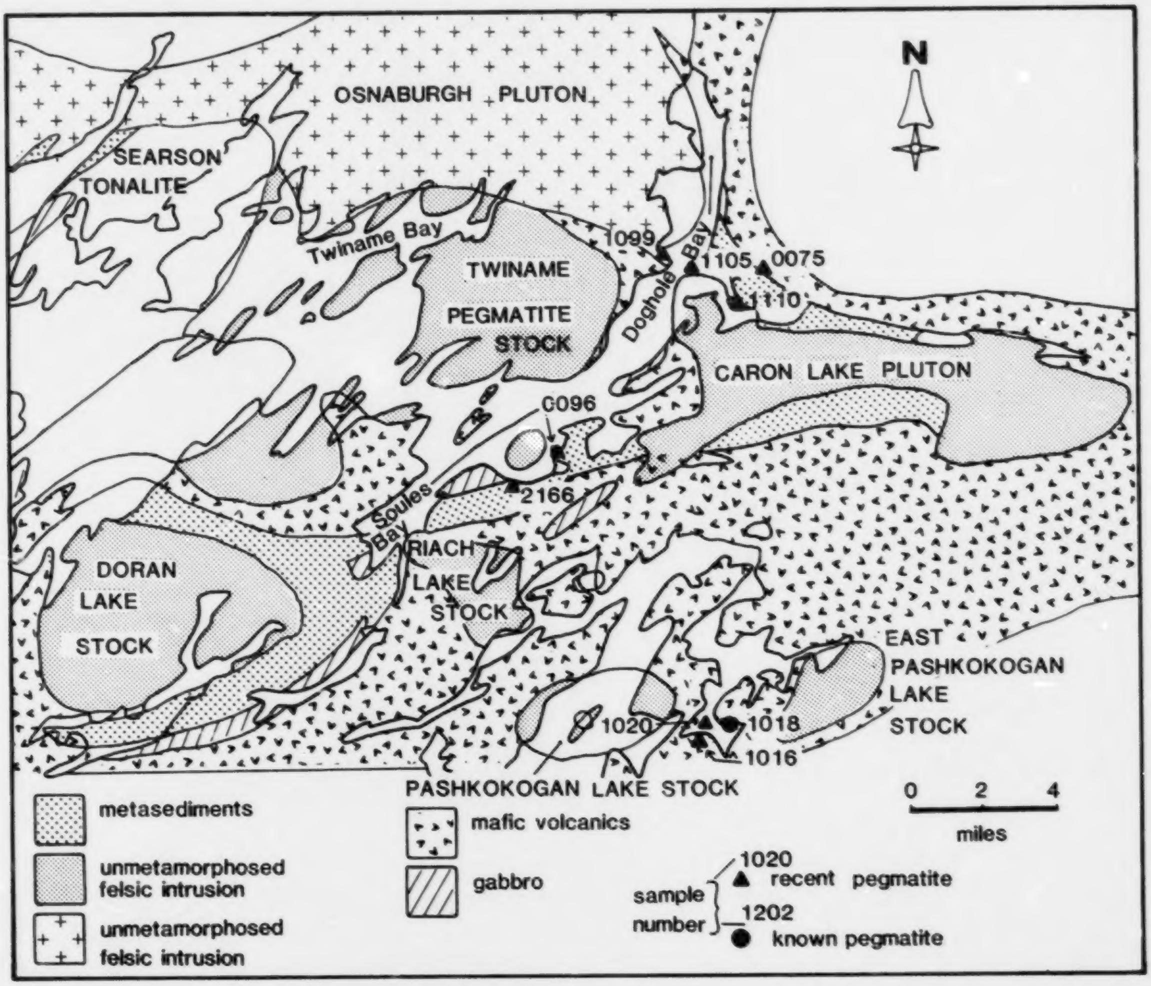

N
OSNABURGH PLUTON
SEARSON TONALITE
Twiname Bay
TWINAME PEGMATITE STOCK
Doghold Bay
1099
1105
0075
1110
CARON LAKE PLUTON
0096
2166
Soules Bay
RIACH LAKE STOCK
DORAN LAKE STOCK
EAST PASHKOKOGAN LAKE STOCK
1020
1018
1016
PASHKOKOGAN LAKE STOCK
0
2
4
miles
metasediments
unmetamorphosed felsic intrusion
unmetamorphosed felsic intrusion
mafic volcanics
gabbro
sample number
1020
recent pegmatite
1202
known pegmatite

Figure 2. Location of pegmatite occurrences. (Project 5.)

phide horizons were mapped, one on East Pashkokogan Lake and the other north of Pedlarpath Bay, on eastern Lake St. Joseph. These were sampled for gold assay and returned minimal values. The East Pashkokogan occurrence, although not recorded in the assessment files, had been trenched in two locations over distances of 7 m and 6 m, respectively. Mineralization encountered here consisted of massive pyrite and pyrrhotite in a black, possibly graphitic, chert matrix.

Despite the overall apparent lack of visible mineralization in those areas studied on eastern Lake St. Joseph, numerous grab samples were taken for gold assay. In general, these samples yielded <20 ppb gold with few exceptions.

The western Lake St. Joseph area appears slightly more promising for potential economic mineralization. The intensely carbonatized mafic volcanic horizon adjacent to the Bamaji-Blackstone batholith is the most likely candidate for gold mineralization. These rocks host rusty weathering iron-carbonate ± quartz ± pyrite ± magnetite pods in addition to foliation-parallel iron-carbonate stringers. Although the authors sampled these pods for gold assay and they returned minimal values (Geoscience Laboratories, Ontario Geological Survey, Toronto), the intensity of the alteration and the volume of rock affected makes further sampling well warranted. In addition to this horizon, numerous sulphide showings have been recorded by this field crew and others in the area including a gold + silver occurrence east of Eagle Island. These showings can be seen on Figure 4.

The gold + silver occurrence east of Eagle Island was originally held by Noranda Incorporated in 1977. An assay of 0.32 ounce gold per ton and 0.28 ounce silver per ton from a grab sample containing pyrite, pyrrhotite, and arsenopyrite was reported at that time. The gold occurrence is currently staked by R.J. Rupert of Sault Ste. Marie, Ontario. It was mapped at 1:100 in order to determine the structural setting with respect to the subprovince boundary and to document the nature of the host rock and mineralization. Results of this mapping are shown in Figure 5.

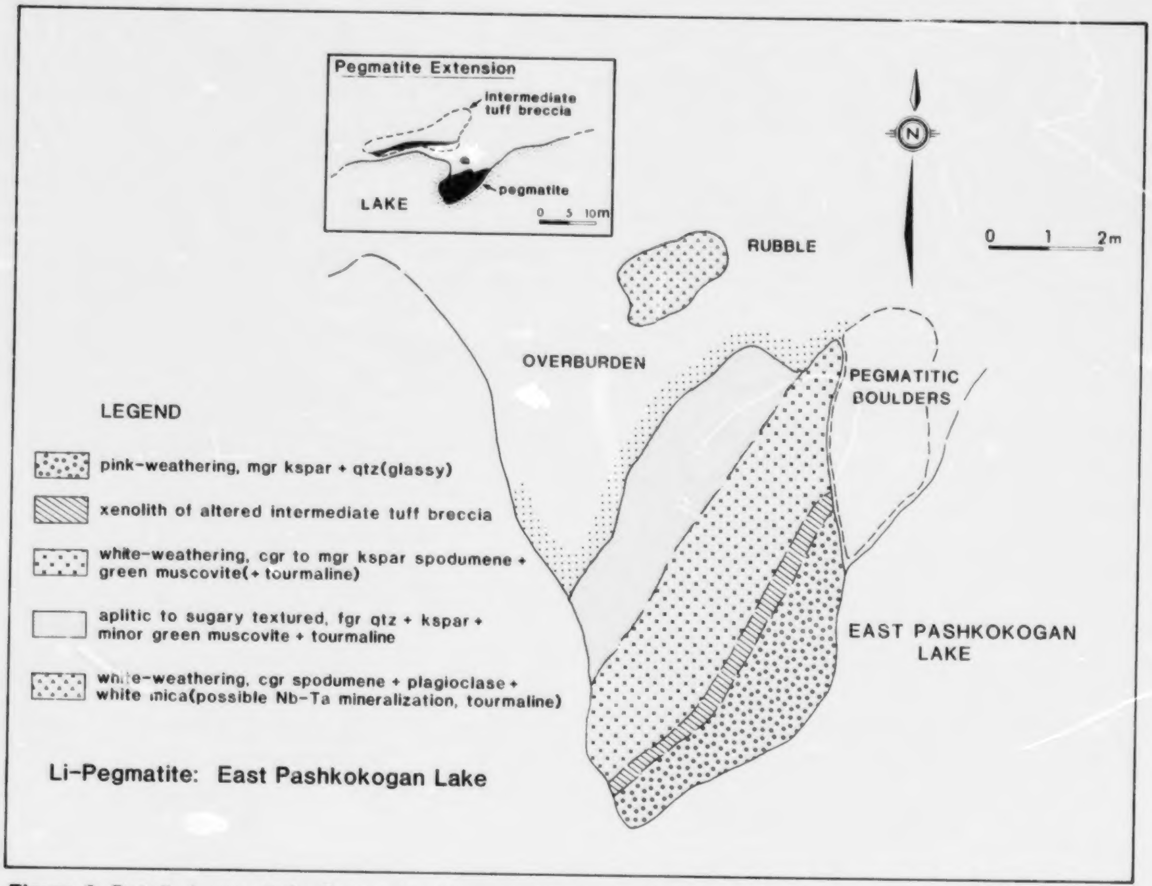

Pegmatite Extension
intermediate tuff breccia
pegmatite
LAKE
0 5 10m
RUBBLE
0 1 2m
N
OVERBURDEN
PEGMATITIC BOULDERS
EAST PASHKOKOGAN LAKE
LEGEND
pink-weathering, mgr kspar + qtz(glassy)
xenolith of altered intermediate tuff breccia
white-weathering, cgr to mgr kspar spodumene + green muscovite(+ tourmaline)
aplitic to sugary textured, fgr qtz + kspar + minor green muscovite + tourmaline
white-weathering, cgr spodumene + plagioclase + white mica(possible Nb-Ta mineralization, tourmaline)
Li-Pegmatite: East Pashkokogan Lake

Figure 3. *Detailed map of the Fairservice Li-pegmatite occurrence, East Pashkokogan Lake. (Project 5.)*

The outcrop consists of interbedded graphitic shale, sideritic chert breccia, and massive chert horizons. The chert bands which are black weathering and aphanitic, are continuous over the length of the outcrop, ranging in width from 7 to 20 cm and are locally offset by east-west-trending transcurrent faults.

The chert breccia beds comprise a major part of the outcrop. These are up to 2 m wide and are laminated on a scale of 1 to 3 m. Chert breccia fragments are white weathering, sugary textured, tabular shaped to subangular and are commonly oriented subparallel to bedding. These fragments are set in a matrix of very fine grained, rusty brown weathered, sideritic argillite or siltstone.

The sulphide-bearing unit at this showing appears to be a graphitic shale. It dominates the western end of the outcrop, where it is tightly folded and appears to be rhythmically interlayered with black weathering chert beds. The shale is rusty brown to black weathering and aphanitic. It contains sulphide mineralization both as fine grained disseminated crystals and as fine (1 mm) laminations. Pyrite and pyrrhotite was the only sulphide mineralization noted. Noranda Incorporated reported arsenopyrite, but none was identified during the course of mapping.

This gold showing does not appear to be structurally related to the dextral shear zone which forms a broad deformation band near the subprovince boundary. Instead, dominant S-folding of the metasediments and a steep, easterly plunging mineral lineation identify the rock fabric as characteristic of the southern limb of the major east-west-trending anticline, the hinge line of which passes through Eagle Island.

On the northwestern side of Eagle Island, the Algoma Steel Corporation Limited has intersected interesting gold values in drill core through the base of the ironstone in association with pyrite (D. Szekely, Algoma Steel Corporation Limited, private company data not on public file, personal communication, 1985).

The remaining group of active claims is located on a sulphide occurrence near the mouth of Johnston Bay. These claims are currently held by Noranda Incorporated and are shown in Figure 1. The area covered consists primarily of intensely iron-carbonatized mafic volcanic rocks. Massive, brick-red iron carbonate pods up to 2 m across are a common feature in these volcanic rocks. These pods are foliation parallel and locally contain deformed discontinu-

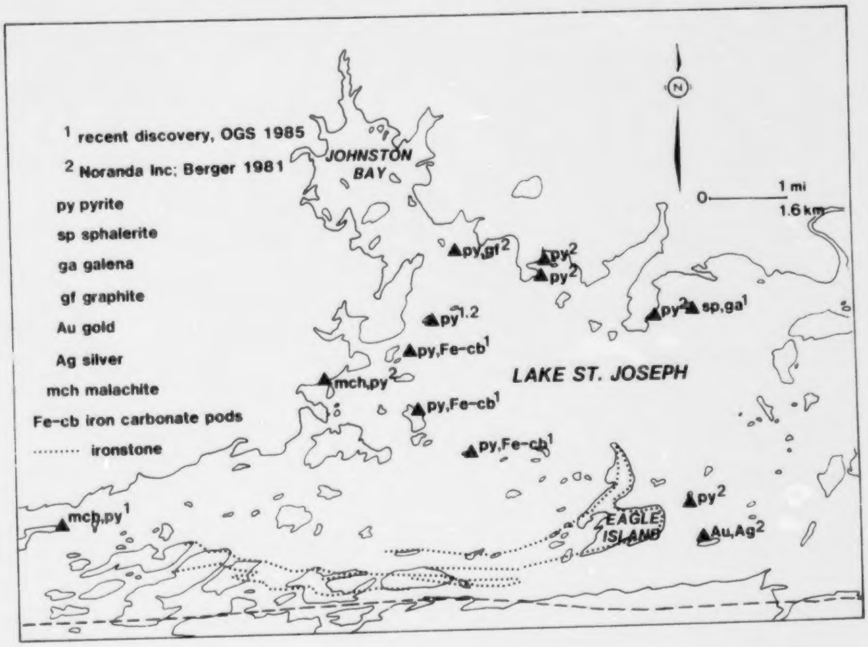

1 recent discovery, OGS 1985
2 Noranda Inc; Berger 1981
py pyrite
sp sphalerite
ga galena
gf graphite
Au gold
Ag silver
mch malachite
Fe-cb iron carbonate pods
ironstone
JOHNSTON BAY
LAKE ST. JOSEPH
EAGLE ISLAND
N
0
1 mi
1.6 km
py,gf2
py2
py2
py1,2
py,Fe-cb1
mch,py2
py,Fe-cb1
py,Fe-cb1
py2
sp,ga1
mch,py1
py2
Au,Ag2

Figure 4. Mineral occurrences in the western Lake St. Joseph area. (Project 5.)

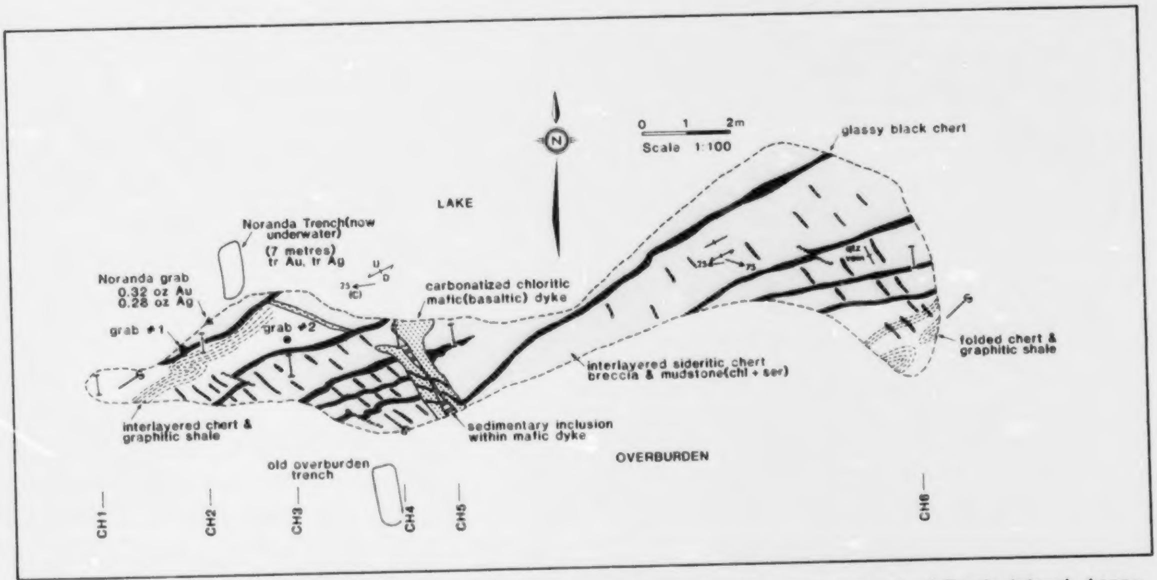

N
0
1
2m
Scale 1:100
LAKE
glassy black chert
Noranda Trench(now underwater)
(7 metres)
tr Au, tr Ag
Noranda grab
0.32 oz Au
0.28 oz Ag
grab #1
grab #2
carbonatized chloritic mafic(basaltic) dyke
interlayered sideritic chert breccia & mudstone(chl + ser)
folded chert & graphitic shale
interlayered chert & graphitic shale
sedimentary inclusion within mafic dyke
OVERBURDEN
old overburden trench
CH1
CH2
CH3
CH4
CH5
CH6

Figure 5. Detailed map of the R.J. Rupert (Noranda Incorporated) gold showing, east of Eagle Island. Assay samples taken by the Ontario Geological Survey are shown as CH1 to CH6 (50 cm chip samples) and Grab #1 and #2 (grab samples). (Project 5.)

ous quartz + chlorite pods but no sulphide mineralization.

An intensely silicified and pyritized contact between pillowed volcanic rocks and a dacitic pyroclastic unit was also noted within these claims. This contact is located on a small island southwest of Johnston Bay. It is marked by a 2 m wide, massive, white to rusty weathering quartz vein. This vein parallels the contact between the two units and appears to have associated sulphide mineralization.

The remaining mineral occurrences shown on Figure 4 include those compiled from the assessment file data and new showings outlined by the present mapping program.

RECOMMENDATIONS FOR EXPLORATION

Numerous assay samples for gold and other elements were collected in this region and the analyses by the Geoscience Laboratories, Ontario Geological Survey, Toronto, show very low gold values. Assay results of up to 230 ppb gold were obtained locally in western Lake St. Joseph. Potentially the most attractive area for gold exploration is in the hinge zone of the large anticline of western Lake St. Joseph and within the later transcurrent shear zone along the southern margin of the belt.

The anticline has refolded a synclinal ironstone-rich sedimentary basin exposed on Eagle Island. Since the refolded ironstone is concentrated close to the base of this sedimentary basin it may form a suitable structural trap for hydrothermal fluids that were derived from the underlying volcanic pile and focused along the hinge zone of the anticline.

The transcurrent shear zone forms a broad deformation band south of Eagle Island and appears to be superimposed upon the earlier regional fold. It has refolded the ironstone beds into large Z structures along the southern limb of the major anticline in western Lake St. Joseph. The shear zone has affected a wide range of rock types including felsic to intermediate pyroclastics at the western end of Lake St. Joseph and on Pashkokogan Lake.

This general stratigraphic and tectonic setting exposed in western Lake St. Joseph is comparable to the Geraldton gold camp along the boundary between the Wabigoon and Quetico Subprovinces.

PEGMATITES

Figure 2 shows the locations of pegmatite dikes examined and sampled by field party personnel for potential rare element mineralization during the 1985 mapping program. With the exception of the known Li-bearing pegmatite on East Pashkokogan Lake, these dikes are previously undocumented occurrences. Two main areas of dike concentration were noted:

1. East Pashkokogan Lake, and
2. eastern Lake St. Joseph, in particular Doghole Bay and northeast of Soules Bay.

These areas are discussed separately below.

EAST PASHKOKOGAN LAKE

The known Li-bearing pegmatite on East Pashkokogan Lake, shown on Figures 1 and 2, lies within the only active claim group in the eastern Lake St. Joseph greenstone belt. It is currently held by R.J. Fairservice of Kenora, Ontario. Placer Development Limited staked the pegmatite in 1980 and conducted a ground geophysical survey and detailed mapping program at that time. Results of this work were inconclusive as far as determining the boundaries of the dike were concerned, and little attempt appears to have been made to find similar pegmatite occurrences in the area. Our mapping, however, has revealed two previously unrecorded pegmatite dikes immediately west of the Fairservice Li occurrence as well as a thin (2 m) dike exposed approximately 10 m due north of the main showing, trending subparallel to the main dike.

These additional dikes share the following features:

1. they are lensoidal, pinching, and swelling along strike; widths range from 2 to 15 m and exposed lengths range from 2 to 30 m;
2. they commonly occur as *en echelon* sets which trend east-west, subparallel to foliation;
3. they are pink weathering and homogeneous;
4. they contain a common and consistent mineral assemblage (*see* Table 2) of coarse grained, blocky potassium feldspar with interstitial glassy quartz and white weathering plagioclase, medium grained green muscovite, euhedral black tourmaline, and fine grained red garnets; and
5. a pervasive tourmaline alteration halo is associated with the dikes; this manifests as tourmaline rims along dike margins and tourmaline ± quartz-rich veinlets which crosscut foliation in the surrounding wall rock.

The authors sampled dikes to determine rare element concentrations and assess the degree of fractionation. A summary of the sample results (analyses by Geoscience Laboratories, Ontario Geological Survey, Toronto) is listed in Table 3 (samples 1016A and 1020A) and is discussed under the Li-pegmatite description.

The Li-bearing pegmatite differs from the above-mentioned dikes in that, like most pegmatites which contain economically interesting mineralization, it displays a crude mineralogical and textural zonation. The Fairservice showing, which was mapped in detail at a scale of 1:100, is shown in Figure 3. It consists of four asymmetrically distributed units consisting of:

1. medium grained quartz and potassium feldspar;
2. medium to coarse grained spodumene + green muscovite + potassium feldspar + tourmaline;
3. aplitic to sugary textured quartz + potassium feldspar + tourmaline + minor green muscovite; and
4. coarse grained spodumene + feldspar + white muscovite + tourmaline ± Nb-Ta mineralization.

Fine grained red garnets are disseminated throughout these units and individual blue-green apatite crystals occur locally.

The dike is currently exposed over a width of approximately 10 m and a strike length of 12 m. The exact boundaries of this pegmatite have still not been established, but they likely exceed these dimensions; it trends into the lake to the west and disappears under overburden to the northeast.

Chip samples taken by Goodwin (1965) returned values of 1.25% LiO_2 over the dike width. Grab sample results from the present survey summarized in Table 3, give comparable values ranging from 0.71% to 0.13% LiO_2 (7100 ppm and 1260 ppm). The highest lithium values were obtained from the aplitic to sugary textured, tourmaline-rich zone of the pegmatite.

The remaining rare element concentrations reported in Table 3 are generally equal to or greater than background values (also listed in Table 3) given

TABLE 2. MINERAL ASSEMBLAGES OBSERVED IN EASTERN LAKE ST. JOSEPH AND EAST PASHKOKOGAN LAKE PEGMATITES. (PROJECT 5.)

Mineral	Pegmatite					
	East Pashkokogan Lake			Eastern Lake St. Joseph		
	Fairservice (1018)*	1016	1020	0096	1110	2166
Quartz	X	X	X	X	X	X
Plagioclase	X	X	X	X	X	X
Orthoclase	X	X	X	X	X	X
Spodumene	X					
Muscovite	X	X	X	X	X	X
Tourmaline	X	X	X	X	X	X
Garnet	X	X	X	X	X	X
Apatite	X		X			
Columbite-Tantalite ?	X	X				

* numbers indicate station location

TABLE 3. RARE METAL CONCENTRATIONS IN PEGMATITE DIKES. (PROJECT 5.)

Sample	Li ppm	Ta ppm	Nb ppm	Cs ppm	Be ppm	Ti %TiO_2	Bi ppm	Sn ppm
East Pashkokogan Lake								
1016A	10	80	38	32	140	0.03	<0.1	87.1
1018A	7100	26	31	115	140	0.03	0.2	136
1018B	1260	19	36	33	100	0.05	0.1	133
1018G	90	16	49	110	110	<0.01	0.1	126
1020A	16	23	26	130	150	0.05	<0.1	36.1
Eastern Lake St. Joseph								
0075B	5	23	36	50	15	0.05	2.7	4.6
background in felsic intrusions***	40	20	10	2-6	20*	0.25	0.1	16.3**

* background concentration in pegmatites
** background concentration in Sn-bearing granites
*** from Handbook of Geochemistry, 1978

for felsic intrusions or pegmatites. The only exception is titanium which occurs in uniformly low amounts (approximately 0.03% TiO_2). Tantalum and niobium occur in concentrations up to four times background levels, with Nb > Ta in all samples except 1016A. Cesium and beryllium concentrations, respectively, average twenty to twenty-five and five to seven times background levels. Tin is also uniformly high, averaging two to four times background levels.

From the rare element concentrations obtained, the East Pashkokogan pegmatite suite is clearly highly fractionated and therefore may characterize a zone of economic interest.

A potential parental granite for these pegmatites was not identified in the Pashkokogan or East Pashkokogan Lake areas. Neither of the two small granitoid stocks mapped nearby exhibit characteristics commonly found in parental granite bodies (Meintzer *et al.* 1984; Trueman and Cerny 1982). A possible source for the pegmatites may lie farther south in the English River Subprovince. Alternatively, the dikes may be part of a progressively fractionated suite derived from the Twiname Pegmatite stock or the Caron Lake stock (Figure 2). This aspect is reviewed later.

EASTERN LAKE ST. JOSEPH

Pegmatite dikes observed in the eastern Lake St. Joseph area are largely concentrated on Doghole Bay and northeast of Soules Bay (*see* Figure 2). These dikes, like those seen on East Pashkokogan Lake, trend approximately east-west, subparallel to foliation. Mineralogically, they are similar to the East Pashkokogan suite (*see* Table 2) with the notable exception that the potassium feldspar crystals commonly contain graphic quartz intergrowths. Typical mineral assemblages consist of potassium feldspar + quartz (both as graphic intergrowths and interstitial crystals) + plagioclase + muscovite (ranging in colour from grey to green) + tourmaline + garnet.

Tourmaline alteration haloes associated with the East Pashkokogan pegmatites are also observed along the margins of the Lake St. Joseph dikes. Individual tourmaline crystals are seen disseminated throughout the wall rock for widths of 1.5 m or more. Locally, tourmaline crystals are pervasively developed adjacent to ironstone beds within intruded sediments and randomly distributed, disseminated green muscovite booklets are noted replacing staurolite.

Texturally, the eastern Lake St. Joseph pegmatites differ from the East Pashkokogan dikes in that they contain the previously mentioned graphic quartz intergrowths in the potassium feldspar and unusual, radiating aggregates of finely interleaved quartz and muscovite. These quartz + muscovite intergrowths occur mainly in two forms:

1. as medium to coarse grained veins which crosscut the pegmatites as an apparently late alteration feature; and
2. as finer grained discrete "inclusions" up to 25 cm across.

The latter form intergrowths which are locally so finely interleaved that they resemble sillimanite. It is quite likely that these intergrowths represent a retrograde reaction after sillimanite and reflect the peraluminous chemistry of the pegmatites. These quartz + muscovite aggregates are best developed in the dikes in the Doghole Bay area, where they locally comprise up to 15% of the pegmatite.

With the exception of one dike northeast of Soules Bay, the pegmatites observed are largely homogeneous. Dike exposures, which range in size from 6 to 70 m in width and up to 70 m in strike length, show little variation in texture or mineralogy. The above mentioned exception shows a textural zonation and varies from a sugary textured, fine grained or aplitic unit to a coarser grained, blocky pegmatitic unit. Muscovite is noteworthy in this dike because it is an unusual silvery green colour and locally occurs in pods up to 40 cm across. Muscovite and potassium feldspar in this pegmatite, and the other eastern Lake St. Joseph occurrences have been sampled to determine rare element content and relative degree of fractionation. Only one sample result is available at the time of writing and this is included in Table 3 (sample 0075A). Rare element concentrations in this sample, although slightly lower than those seen in the East Pashkokogan suite, still exceed background levels for Ta, Nb, Cs, and Bi, suggesting that these dikes are moderately well fractionated.

Two possible parental intrusions exist for the pegmatite dikes. These are the Caron Lake pluton and the Twiname Pegmatite, socated southeast and southwest respectively of Doghole Bay. The Twiname Pegmatite stock has only recently been subdivided from the granitoid complex to the north by Stott (*see* this volume). These intrusions, shown on Figure 2, display characteristics common to rare-element associated granites.

According to Trueman and Cerny (1982), granitic intrusions parental to rare element pegmatites are generally small to moderate in size, averaging 5 to 150 km^2 in surface area. Both the Caron Lake and the Twiname Pegmatite stocks are within this size range, at approximately 65 km^2 and 145 km^2, respectively.

The two unmetamorphosed plutons are post-tectonically emplaced near the Lake St. Joseph greenstone-granitoid contact. This contact represents a major lithological boundary between the Lake St. Joseph granitoid complex to the north and the greenstone belt. Granitic intrusions parental to pegmatites often intrude along such large-scale lithological boundaries between units of marked competency contrast (Trueman and Cerny 1982).

Parental intrusions are also generally leucocratic, peraluminous granites or granodiorites, which contain both biotite and muscovite and are pegmatitic to medium grained (Meintzer *et al.* 1984). Common mineral assemblages in these intrusions consist of graphic quartz + potassium feldspar and blocky potassium feldspar + plagioclase + muscovite + biotite + tourmaline + garnet. The Caron Lake pluton is a leucocratic, fine to medium grained two-mica granodiorite which locally contains fine grained garnets and tourmaline. The Twiname Pegmatite stock is a pegmatitic intrusion characterized by abundant quartz-muscovite intergrowths and local development of fine grained garnet and tourmaline.

Further sampling and mapping of the above-mentioned intrusions, and the eastern Lake St. Joseph area, is necessary in order to firmly establish the relationship between the plutons and the observed pegmatite dikes. Preliminary evaluation, however, as discussed above, strongly suggests that either one or both of these intrusions may be a candidate as the parental body to a fractionated suite of pegmatite dikes.

A sampling program has been initiated by the present survey to determine if a regional zoning of progressive rare-element enrichment occurs at a distance from these plutons. To test for such zoning relationships, the authors have sampled both the muscovite and potassium feldspar from several pegmatite dikes to establish Li, Rb, and Cs contents in each and draw comparisons after Gordiyenko (1971). Analyses of K/Cs versus Na_2O are also being evaluated for potassium feldspars from these dikes following the method proposed by Gordiyenko (1976).

RECOMMENDATIONS FOR FUTURE EXPLORATION WORK

The degree of fractionation of the eastern Lake St. Joseph and East Pashkokogan Lake pegmatite suites is favourable for potential economic rare element mineralization, notably Ta and Cs. The possibility that the two suites may be related and reflect a mineralogical and textural zonation from a single parental intrusion or several related stocks greatly increases the area of economic potential. Further work, in the form of reconnaissance mapping and sampling is warranted to establish rare-element and textural zoning patterns and to locate additional unmapped dikes in the region. More detailed examination should follow this to determine average rare-element concentrations within the pegmatite suites.

Pegmatite dikes of similar texture and mineralogy as those seen in the eastern Lake St. Joseph area have also been noted at the western end of the lake. These occur in close proximity to the subprovince boundary and intrude sediments east of Root Bay. Unfortunately, due to a shortage of time, these were examined only briefly. Their strong resemblance to the dikes discussed above, however, suggests that they also warrant a reconnaissance evaluation of geochemical indicators (Gordiyenko 1971, 1976).

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6. Geology of the Rat Portage Bay Area, Lake of the Woods, District of Kenora

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INTRODUCTION

Field investigations carried out in 1985 represent the second half of a two-year project of detailed geological mapping (1:15 840 scale) of the northern part of Lake of the Woods. Work in 1984 was concentrated on the eastern half, the Bigstone Bay area (Ayer 1984). In 1985, mapping was extended westward into north-central part of Lake of the Woods. An area of about 300 km^2 was mapped, bounded by Latitudes 49°35'N and 49°45'N, and Longitudes 94°28'W and 94°41'W.

Most of the area is accessible by boat from Lake of the Woods. The northwestern part can be reached from Highway 17 and numerous gravel surfaced secondary roads.

MINERAL EXPLORATION

Unless otherwise stipulated, the following information has been derived from the Assessment Files of the Resident Geologist's office, Ontario Ministry of Northern Affairs and Mines, Kenora (AFK).

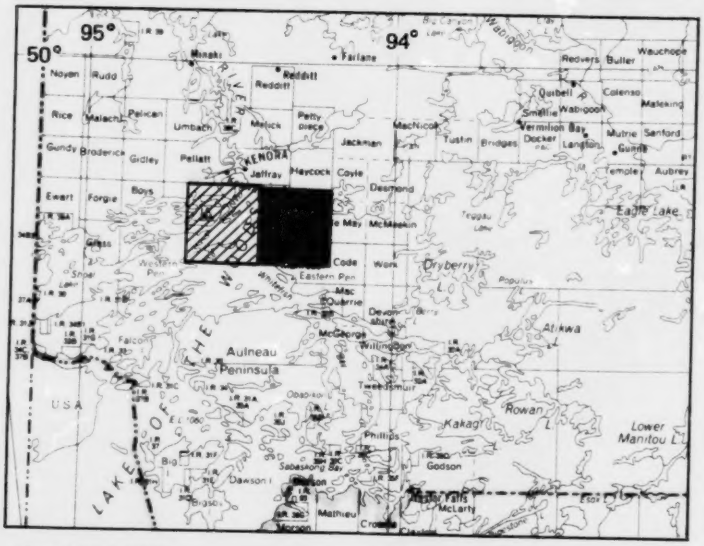
The map area has been explored for gold since the first gold discovery on Lake of the Woods in 1879. Several periods were quite active, the first was from the 1880s to 1900, during the "Lake of the Woods Gold Rush". The Minerva Mine property (C on Figure 1) had a production of 30 ounces of gold from 28 tons of selected ore in 1885 (AFK).

A second period of activity was from the late 1930s to early 1940s. The largest producer in the map area, the Kenricia Mine property (B) produced a total of 2533 ounces gold and 521 ounces silver from 1939 to 1940 (Beard and Garratt 1976).

A third period of increased gold exploration began in the mid 1970s and continues to present.

The Kenricia Mine area was explored by a combined ground electromagnetic and magnetometer survey in 1975 by Aumac Explorations Limited. From 1974 to 1975, Hudson Bay Exploration and Development Company Limited undertook a ground electromagnetic survey followed by four diamond-drill holes northeast of the Kenricia Mine, on conductors around Abernethy Lake.

An area of 59 claims including the aforementioned ground, was geologically mapped and old trenches were stripped and resampled by Atikwa Resources Incorporated in 1983. This ground is currently held by W. Whymark. The Nor-Penn property (D) was discovered in 1947 and transferred the following year to Nor-Penn Mines Limited. Up to the early 1950s, the property was mapped and trenched and some minor diamond drilling was done. In 1974, Hudson Bay Exploration and Development Company Limited drilled one hole on the property and eight



LOCATION MAP

Scale : 1 : 1 548 000 or 1 inch to 25 miles

■ 1984 Map Area

▨ 1985 Map Area

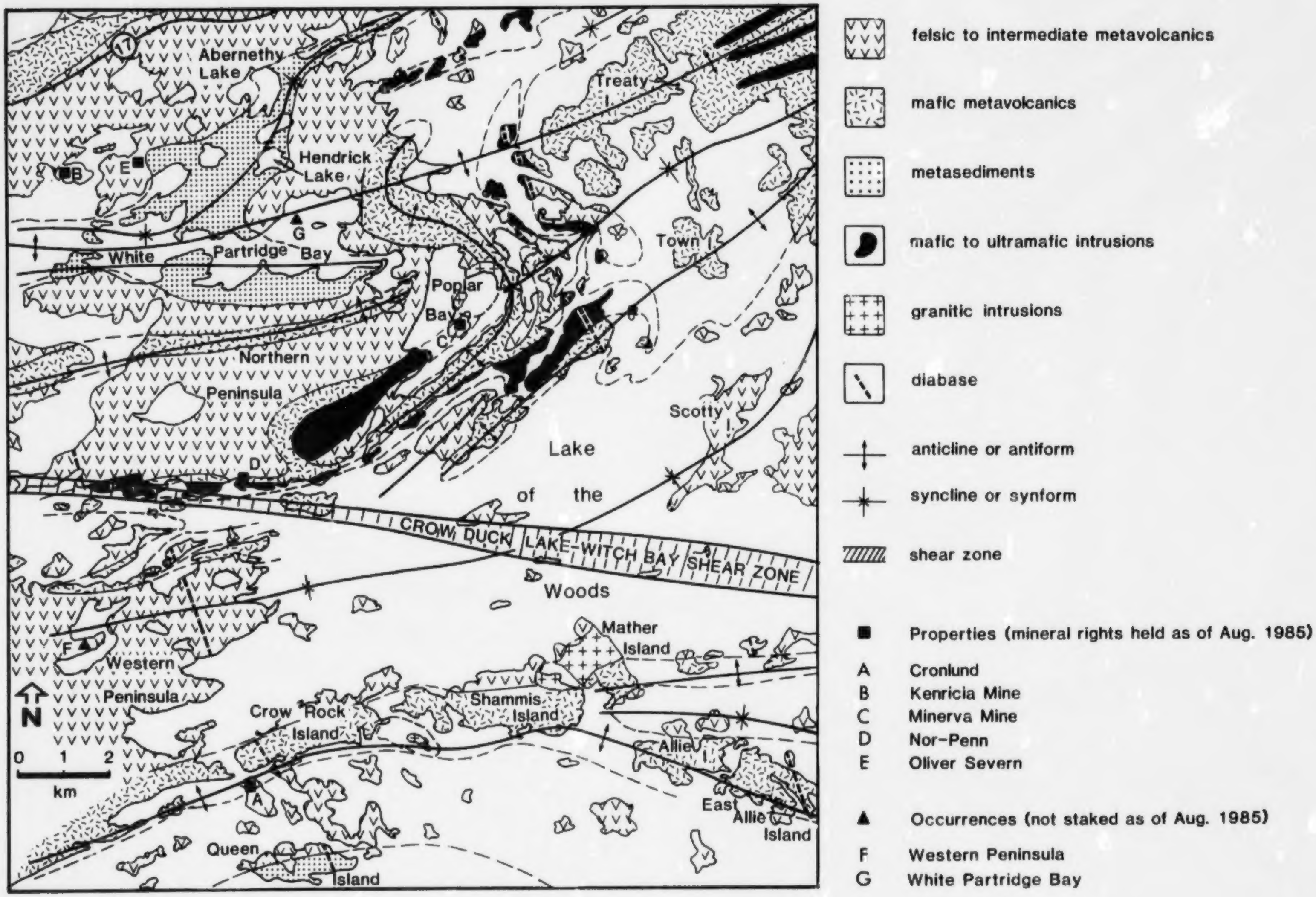

felsic to intermediate metavolcanics
mafic metavolcanics
metasediments
mafic to ultramafic intrusions
granitic intrusions
diabase
anticline or antiform
syncline or synform
shear zone
Properties (mineral rights held as of Aug. 1985)
A Cronlund
B Kenricia Mine
C Minerva Mine
D Nor-Penn
E Oliver Severn
Occurrences (not staked as of Aug. 1985)
F Western Peninsula
G White Partridge Bay
17
Abernethy Lake
Hendrick Lake
White Partridge Bay
Poplar Bay
Northern Peninsula
Treaty
Town I.
Scotty I.
Lake of the Woods
CROW DUCK LAKE-WITCH BAY SHEAR ZONE
Mather Island
Shammis Island
Crow Rock Island
Western Peninsula
Allie I.
East Allie Island
Queen Island
N
0 1 2
km

Figure 1. Generalized geology and property locations in the Rat Portage Bay area. (Project 6.)

more several kilometres north and northeast of the property. From 1980 to 1981, Raleigh Minerals Limited undertook a program of limited geological mapping, a geochemical survey, and three diamond-drill holes. In 1983, Academy Explorations Limited cleaned and resampled old trenches and diamond drilled five holes. The property is presently under option to Homestake Explorations Limited who have flown an airborne geophysical survey, and during the 1985 field season have undertaken a program of stripping, resampling old trenches, and geological mapping. In 1981, Denison Mines Limited acquired the Minerva Mine property (C) and did a program of geological, geophysical, and geochemical surveys as well as cleaning out and resampling the old trenches.

GENERAL GEOLOGY

The first published geological map of the Lake of the Woods was by Lawson (1885). The map area is included in the 1 inch to 1 mile (1:63 360) map by Thomson (1937). Parts of the southeastern and southwestern parts of the map area have been previously mapped at 1/4 mile scale (1:15 840) by Davies (1967, 1970). The area to the east was recently mapped by the author (Ayer *et al.* 1985a, 1985b). The area to the north has been mapped by King (1983).

All rocks in the map area are of Archean age, with the exception of northwest-trending Early Proterozoic diabase dikes. The oldest unit is pillowed to massive submarine mafic flows. This unit is correlative with tholeiitic basalts of the Lower Mafic unit in the Bigstone Bay area to the east, where a maximum stratigraphic thickness of 8 km is exposed (Ayer *et al.* 1985a). In the Rat Portage Bay area predominantly the upper part of this unit is exposed. This upper part is characteristically iron enriched (relatively high aeromagnetic profile) and is locally amygdaloidal and variolitic. Some flows are porphyritic with plagioclase phenocrysts up to several centimetres.

The lower mafic unit is conformably overlain by a diverse sequence of predominantly subaqueous, calc-alkalic felsic to intermediate volcanic rocks designated the Upper Felsic unit. These deposits are predominantly debris flows ranging from coarse heterolithic units, grading into fine, crystal-rich, sandy tuffs and/or siltstones. Subordinate amygdaloidal and/or pillowed, plagioclase-rich intermediate flows are present in the area south and northeast of White Partridge Bay, overlain in the area northeast of White Partridge Bay by felsic tuffs which locally exhibit relict eutaxitic textures and may be in part subaerial.

Locally intercalated within the Upper Felsic unit are sedimentary sequences consisting of greywacke, siltstone, argillite, and minor ironstone (predominantly pyritic argillite and minor thickly laminated chert and magnetite ironstone).

Mafic flows within the overlying pyroclastics occur centred on first phase anticlines and are interpreted as infolds of the Lower Mafic group.

A thick horizon of well-bedded distal turbidites occurs in the southern part of the map area extending south of the map area to a maximum thickness of over 2 km.

In the White Partridge Bay, area a thick sedimentary succession overlies the Upper Felsic unit. These sediments are herein designated the White Partridge Bay group. The group consists of a transgressive sequence grading from well-bedded, fine grained greywacke and argillite at the base upwards into massive medium grained sandstone to conglomerates at the top. The conglomerates occur in the central part of the group from the northeast part of White Partridge Bay to Hendrick Lake. The conglomerates range from the massive-graded to graded-stratified facies of Walker (1984) and are locally interbedded with planar crossbedded sandstones. Clasts range from subangular to subrounded and consist of porphyritic, hypabyssal rocks, mafic and felsic metavolcanics, granitoids, quartz and banded ironstone pebbles. They were probably deposited in a submarine canyon fan, proximal to the feeder channel of the turbidity deposits.

Mafic sills intrude the volcanic rocks and are locally differentiated displaying an ultramafic composition at the base grading upward to gabbro and leucogabbro. Quartz and/or feldspar porphyry dikes, sills, and small stocks locally cut the volcanic rocks.

Small granitoid stocks ranging in composition from tonalite to syenite cut the metavolcanics. The Lower Mafic unit in the northwestern corner of the map area is intruded by an alkali feldspar megacrystic granodiorite in which gneissic layering is progressively developed towards the north. The granodiorite occurs along the contact between volcanic rocks of the Wabigoon Subprovince and tonalitic gneisses of the Winnipeg River belt to the north. It has been traced for at least 30 km and ranges from 100 to 700 m thick (Beakhouse 1985).

Metamorphic grade ranges from greenschist facies throughout most of the supracrustal belt and rises to lower amphibolite facies in the northwestern corner of the map area within a kilometre or so of the contact with the Winnipeg River belt.

STRUCTURAL GEOLOGY

At least two major episodes of folding have resulted in numerous tight, east to northeast-trending folds. In many cases, it is not possible to determine which phase of folding was responsible for the indicated top reversals as the first and second phases have subparallel axes. However, the Y-shaped pattern of lithological units, such as the distribution of the White Partridge Bay group in the northwest and the Lower Mafic unit in the southeast, are interpreted as the result of refolding of earlier folds.

A later deformation has resulted in a pervasive east to east southeast cleavage. Locally, the cleavage is strongly developed as highly schistose carbonatized and sericitized shear zones from several metres to over 1 km in width. The largest of these trends east-southeast across the central part of the map area and is termed the Crow Duck Lake-Witch Bay Shear Zone. It is of regional extent, and has been traced over a length of at least 65 km. Deflection of foliation and lithologic units within the shear zones indicate consistent left lateral movement in the horizontal plane. However, a near vertical fabric and a general lack of large scale horizontal dis-

TABLE 1. OLIVER SEVERN PROPERTY (E ON FIGURE 1) (PROJECT 6)

Sample Description	Au	Ag (ppm)
15 cm quartz vein with pyrite	0.99 oz/ton	<2
quartz vein with pyrite	9600 ppb	15
Wallrock with 10% pyrite	0.93 oz/ton	<2
White Partridge Bay Occurrence (G on Figure 1)		
7 cm quartz vein with pyrite	0.33 oz/ton	<2
10 cm quartz vein with pyrite*	2.42 oz/ton	<2
1 cm quartz vein veinlet with pyrite	560 ppb	<2
quartz vein with pyrite from dump	435 ppb	<2

*NOTE: visible gold observed in the vein but not in the submitted sample

location of lithological units indicates that most movement was probably subvertical.

ECONOMIC GEOLOGY

GOLD

Gold mineralization in the map area occurs mainly in two distinct environments:

1. The first is typified by the Kenricia Mine (property B) in which gold occurs in distinct quartz veins in felsic to intermediate metavolcanics which are not strongly sheared or altered. Gold-bearing quartz veins contain black tourmaline, minor sulphide mineralization (predominantly pyrite), and rarely visible gold. Other examples of this type are the Oliver Severn property (E), White Partridge Bay Occurrence (G), and the Western Peninsula Occurrence (F). Some preliminary assay results of grab samples of vein and wall rock mineralization are presented in Table 1 (Geoscience Laboratories, Ontario Geological Survey, Toronto).
2. The second environment is typified by the Nor-Penn property (D). The gold mineralization occurs in highly schistose and altered rock in a ductile shear zone. Alteration consists of widespread carbonatization and more localized silicification (pervasive and/or quartz-carbonate veining), sericitization (locally with abundant fuchsite), and up to 10% finely disseminated pyrite. Gold is closely associated with silicification and sulphide mineralization. This type of gold environment occurs within mafic volcanic rocks transected by shearing, but typically close to the contact with the overlying felsic volcanic rocks. Resampling of old trenches at the Nor-Penn property (D) by Academy Explorations Limited in 1983 indicated highs of up to 0.28 ounce gold per ton and 0.80 ounce silver per ton over 15 feet and 0.48 ounce gold per ton and 1.32 ounces silver per ton over 5 feet (AFK). Another example of this environment of gold mineralization in the map area is the Cronlund property (A).

RECOMMENDATIONS TO THE PROSPECTOR

Good potential exists for economic gold mineralization within the map area. The mineralization at the Nor-Penn Property is very similar in style to that of Nuinsco Resources Limited Cameron Lake Deposit in sheared, carbonatized, silicified, and sericitized mafic metavolcanics just north of a regional shear zone. The whole length of the Crow Duck Lake-Witch Bay shear zone has high potential and should be carefully examined. Additionally, based on empirical observation of this and the map area to the east (Ayer 1984), the contact area between the lower mafic and overlying felsic volcanic rocks has been a particularly fruitful horizon, with many of the major deposits located near this contact.

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7. Kakagi Lake-Rowan Lake Regional Geology, District of Kenora

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INTRODUCTION

Field work during the summer of 1985 represents the second phase of a project designed to provide a regional synthesis of geological data in the Gibi Lake-Kakagi Lake-Rowan Lake area. The study area, outlined on the location map, has been mapped previously: the Rowan Lake area (Kaye 1973); the Cedartree Lake area (Davies and Morin 1976); the Gibi Lake area in 1979 and 1980 (Trowell, in preparation); the Schistose Lake area (Edwards 1980); the Kakagi Lake area (Kaye 1981); and the Long Bay-Lobstick Bay area (Johns and Richey 1982; Johns and Davison 1983; and Johns *et al.* 1984).

During the 1985 field season, an area centred on Kakagi Lake was studied. The Kakagi Lake group of pyroclastic rocks was traced southwest into Sabaskong Bay of Lake of the Woods (Figure 1). In Figure 2, a tentative stratigraphy and facies analysis of the group are outlined.

Access to the area is provided by Kakagi Lake and all parts can be reached by boat. A road to the Nuinsco Cameron Lake Gold Deposit, currently under construction, will provide access to Cedartree Lake and Stephen Lake.

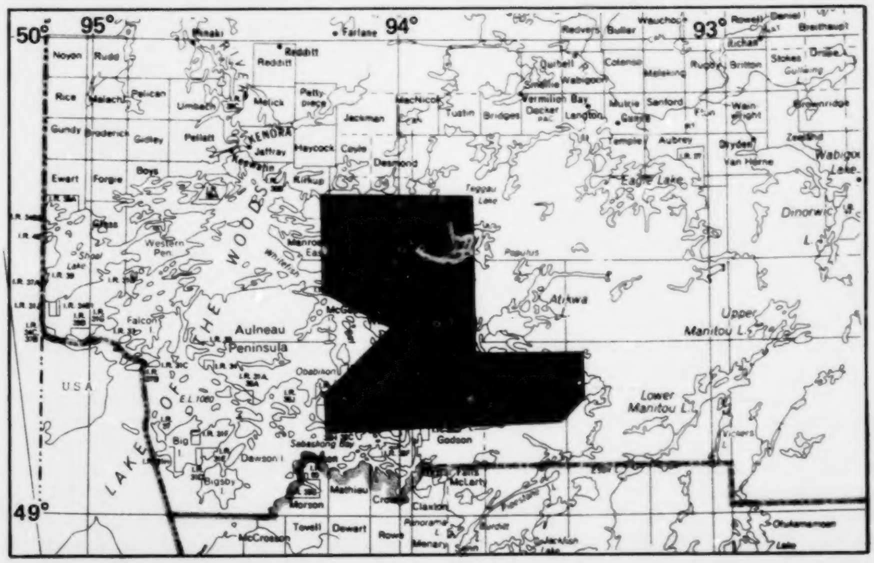
MINERAL EXPLORATION

Gold remains the metal of interest in the Kakagi Lake area. Past exploration has been described by Johns (in press), Davies and Morin (1976), Edwards (1980), and in past volumes of "Report of Activities Regional and Resident Geologists" published by the Ontario Geological Survey. Exploration for gold in the Kakagi Lake area is currently being carried out by Canadian Nickel Company Limited (Canico). Metallgesellschaft Canada Limited is carrying out a diamond drill program for base metals near Wisener Lake. Nuinsco Resources Limited is continuing with a diamond drill program on its Cameron Lake Gold Deposit. During the summer of 1985, Dubenski Gold Mines Limited diamond drilled on the southern shore of Flint Lake and Voyageur Exploration Limited carried out an exploration program around Jessie Lake.

GENERAL GEOLOGY

The study area is situated at the western edge of the Wabigoon Subprovince between Lake of the Woods and the Savant Lake-Crow Lake area (*see* Trowell *et al.* 1980). The Kakagi Lake area is underlain by the Snake Bay formation, Katimiagamak formation, and the Kakagi Lake group.

The Snake Bay formation; consisting of interlayered massive, pillowed, and porphyritic mafic flows intruded by synvolcanic gabbros; underlies the Kakagi Lake group. Its base has been intruded by the Aulneau Batholith (Figure 1). Large irregular synvolcanic gabbro bodies of the Snake Bay formation are massive, homogeneous, medium-grained, in places porphyritic, and some bodies are differentiated. The massive, medium- to coarse-grained gabbros exhibit equigranular to ophitic textures and mineral banding. The differentiated gabbros exhibit metapyroxenite bases that grade rapidly upward into gabbro and porphyritic gabbro. Porphyritic gabbros have rounded plagioclase phenocrysts up to 10 cm in diameter in a fine-grained, equigranular gabbro matrix. Phenocrysts can form up to 40 percent of the rock. Fine-grained massive and pillowed mafic flows in the Snake Bay



LOCATION MAP

Scale : 1 : 1 548 000 or 1 inch to 25 miles

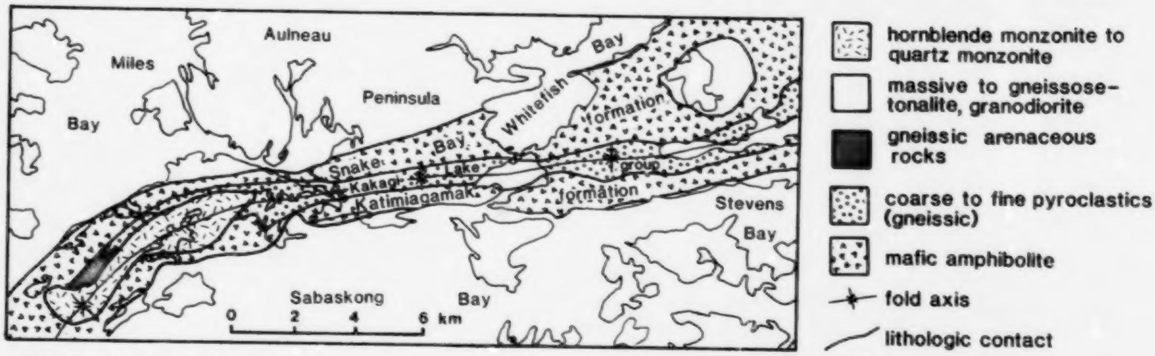


Figure 1. *Distribution of the supracrustal lithologies within Sabaskong Bay west of Whitefish Bay, Lake of the Woods. (Project 7.)*

formation containing similar feldspar phenocrysts (leopard rock) are believed by the author to be the extrusive equivalent of the porphyritic gabbros. Mafic tuff and lapilli-tuff mapped by Davies and Morin (1976) are moderately sorted mafic hyaloclastites and broken pillow breccia. The presence of pillows, pahoehoe toes, and a regolithic breccia cemented by epidote in the top of the Snake Bay formation indicates the formation may have been deposited in a shallow water environment.

The Kakagi Lake group of pyroclastic rocks can be traced beyond Whitefish Bay on Lake of the Woods to Miles Bay on Lake of the Woods (Figure 1). Stretched and contorted, coarse pyroclastics in Sabaskong Bay grade laterally westwards into tuffaceous grey gneiss then into gneissic arenaceous wacke (Figure 1). This gradation is indicative of a progradation into a distal environment. The amphibolite gneiss bounding the fragmental rocks on the north and south (Figure 1) are interpreted to represent metamorphic equivalents of the Snake Bay formation and Katimiagamak formation respectively. Hornblende monzonite to quartz monzonite (Figure 1) exhibiting many features described by Edwards (1982) is believed to be the result of partial melting of the mafic amphibolites of the Katimiagamak formation (Edwards 1982). The Kakagi Lake group overlies mafic metavolcanics, minor intermediate metavolcanics, and gabbro of the Katimiagamak and Snake Bay formations (Figure 2). This group is subdivided into several formations (Figure 2). The contact between the Snake Bay formation and the Emm Bay formation (Kakagi Lake group), in the northwestern part of the area, is very irregular on an outcrop scale.

The group consists of pyroclastic rocks and was deposited by long lived (13.7 MA minimum, Davis and Edwards 1982) intermediate volcanic centres. It can be subdivided into five formations which in order of decreasing age are: the South Kakagi Lake formation, the East Kakagi Lake formation, the Emm Bay formation, the Cedartree Lake formation, and the Stephen Lake formation (Figure 2). The emphasis of the following discussion is on facies analysis of pyroclastic rocks. The nomenclature used is discussed in Easton and Johns (in press).

The South Kakagi Lake formation overlies the Katimiagamak formation (Figure 2; Table 1) and consists of two volcanic facies, an epiclastic plus distal facies (E+D) and a distal plus epiclastic facies (D+E). The rocks of the epiclastic plus distal facies (E+D, Figure 2) were laid down in a basin within the mafic flows of the Katimiagamak formation and consists of well bedded and sorted, quartz-rich feldspar arenite interbedded with thinly laminated chert and massive, fine-grained quartz-feldspar tuff. Quartz feldspar tuff and lithic lapilli-tuff increase both vertically and laterally from the epiclastic plus distal facies and the feldspar arenite and chert decrease proportionally into the distal plus epiclastic facies (D+E, Figure 2).

The East Kakagi Lake formation overlies both the South Kakagi Lake formation and the Katimiagamak formation and is bounded to the north by the South Kakagi Fault (Figure 2; Table 1). Within the formation, the distal plus proximal facies (D+P) is composed of interbedded debris flows, pyroclastic flows and tuff. All these rocks contain phenocrysts. As the South Kakagi Fault is approached, the hornblende phenocryst content of both clasts and matrix increases and correspondingly the quartz phenocryst content decreases. A body of medium- to fine-grained feldspar-hornblende porphyry and associated flows represent a subvolcanic plus flow facies (S+F) of the East Kakagi Lake formation.

The Emm Bay formation overlies both the Snake Bay and Katimiagamak formations and is in fault contact with the East Kakagi Lake formation (Figure 2; Table 1). This is the most extensive and volcanologically most complex formation in the Kakagi Lake group. Most of the formation is composed of interbedded heterolithic, matrix supported lapilli tuff to pyroclastic breccia debris flows and monolithic, matrix supported, lapilli-tuff to pyroclastic breccia pyroclastic flows. Thick, massive, poorly developed beds; lack of grading; and lithologic complexity indicates that both the debris flows and pyroclastic flows were deposited in a proximal volcanic environment (P). To the north on Cedartree Lake and the east towards Cameron Lake (Figure 2) debris flows with rounded, better sorted clasts and matrix occur in a redeposited environment and a proximal plus distal facies (P+D). Hornblende phenocrysts are very common in both clasts and matrix of debris flows and pyroclastic flows throughout the formation.

TABLE 1. FORMATIONS AND VOLCANIC FACIES OF THE KAKAGI LAKE GROUP. SEE FIGURE 2. (PROJECT 7.)

Formation	Volcanic Facies	Lithologies	Structures and Features
South Kakagi Lake formation	D distal deposited + distal redeposited E epiclastic	tuff,lapilli-tuff, ash flow tuff, reworked tuff, arenite, cherty tuff	quartz bearing, monolithic, bedded, graded
	E epiclastic + distal redeposited D distal deposited	arenite, chert, reworked tuff, tuff	monolithic, quartz bearing, bedded, laminated, good sorting, Bouma sequences, soft sediment deformation, flame structures
East Kakagi Lake formation	distal deposited D distal redeposited + proximal deposited P proximal redeposited	tuff, lapilli-tuff, tuff breccia, ash flow tuff, intermediate and mafic intrusions	monolithic, heterolithic, thick beds
	S subvolcanic + intrusions F possible flows	hornblende and hornblende feldspar porphyry	medium-grained to fine-grained
Emm Bay formation	V vent deposited + proximal deposited P	pyroclastic breccia, tuff breccia, tuff, feldspar-porphyry and mafic dikes	monolithic-heterolithic, massive, unsorted, very thick beds, thin graded tuff beds
	E epiclastic + distal redeposited D distal deposited	arenite, reworked tuff and lapillistone, tuff, cherty tuff	bedded, graded, flame structure
	P proximal deposited proximal redeposited	pyroclastic breccia, tuff breccia, lapillistone, lapilli-tuff, tuff, felsic flows, intermediate flows, mafic flows, hornblende feldspar porphyry, feldspar porphyry, mafic dikes	heterolithic, bilithic, monolithic, massive, thick, poorly developed beds, poor sorting, minor grading, flow banding, flow breccia
	P proximal deposited + proximal redeposited D distal redeposited	lapilli-tuff, lapillistone tuff, tuff breccia, feldspar-porphyry and mafic dikes and sills	heterolithic, monolithic, poor to moderate sorting, well rounded clasts, massive poorly bedded
Cedartree Lake formation	D distal deposited + distal redposited E epiclastic	tuff, lapilli-tuff, lapillistone, tuff breccia, arenite, reworked tuff, cherty tuff	bedded, graded, soft sediment deformation, flame structures
Stephen Lake formation	D distal deposited + distal redeposited E epiclastic	tuff, arenite, chert, cherty tuff, pyroclastic breccia, ash flow tuff	bedded, graded, crossbedded, spherulites, soft sediment deformation,flame structures

North of Chase Point on Kakagi Lake, two additional volcanic facies occur within the Emm Bay formation. A vent plus proximal facies (V+P) (Figure 2; Table 1) consists of chaotic, coarse to very coarse, heterolithic to monolithic pyroclastic deposits with very minor thin tuff interbeds. Hornblende phenocrysts are absent from some of the deposits in this facies. Many synvolcanic, intermediate dikes and post volcanic mafic dikes are found within this facies. An epiclastic plus distal facies (E+D, Figure 2; Table 1) in the Emm Bay formation north of Chase Point consists of interbedded arenite, reworked tuff, chert and feldspathic tuff.

The Cedartree Lake formation (Figure 2; Table 1) overlies the Emm Bay formation. It is composed entirely of distal plus epiclastic facies (D+E, Figure 2; Table 1) deposits. These consist of predominantly fine pyroclastic rocks with minor interbedded coarse deposits. A member of the Cedartree Lake formation consisting of thick to thin bedded arenite, wacke, chert and fine ash flow deposits, occurs in eastern Cedartree Lake.

The Stephen Lake formation overlies the Cedartree Lake formation and is composed entirely of distal plus epiclastic facies rocks (D+E, Figure 2; Table 1). It consists of very fine-grained, thick to thin bedded tuff, spherulitic tuff, cherty tuff, reworked tuff, siltstone, and chert containing an abundant variety of sedimentary features.

The Emm Bay formation and the Cedartree Lake formation have been intruded by the differentiated "Kakagi Lake Sills". On Emm Bay, these sills have intruded oblique to bedding (Davies and Morin l976). They cut reworked pyroclastic and epiclastic rocks indicating that they have been emplaced after cessation of volcanism that deposited the Emm Bay and Cedartree Lake formations.

The Point Bay group found around the periphery of the Dryberry Batholith in the Long Bay-Lobstick Bay area (Johns *et al.* 1984) can be recognized in the Dryberry Batholith at a point 2.5 km east of Black Lake. An intrusion breccia consists of very coarse porphyritic anorthositic gabbro; and minor ultramafic and layered gabbro surrounded by fine-grained, white trondhjemite. The anorthositic gabbro is white, massive and difficult to trace into the surrounding rocks where it becomes sheared and banded. The anorthositic gabbro portion of the intrusion breccia has been interpreted as equivalent to the differentiated sills intruding the Point Bay group south of Dryberry Lake (Johns *et al.* 1984).

STRUCTURAL GEOLOGY

The Pipestone-Cameron Fault zone in the Yellow Girl Bay, Lake of the Woods area, was examined by the author. It is about 1.6 to 2.0 km wide. In it the rocks are highly sheared and in places carbonatized. Some of the rocks within the fault zone mapped as tuffs by Fraser (1943) are interpreted by the author to be sheared gabbro to diorite.

Studies by Cuddy (1971) and Osadetz (1979) have shown that the structural history of the Kakagi Lake area is complex. Figure 2 outlines some of the salient features. The South Kakagi Fault (Edwards 1980) separates the East Kakagi Lake formation from the Emm Bay formation. Based on stratigraphy, the assumption is made that the East Kakagi Lake formation and South Kakagi Lake formation have been uplifted relative to the Emm Bay formation. Southwest of Chase Point (Figure 2) a northeast striking thrust fault separates rocks of the Kakagi Lake group from those of the Katimiagamak formation (Figure 2).

Two phases of folding have been proposed by Osadetz (1979). The first is represented by a north- to northeast-trending syncline bisected by the Stephen Lake Stock. The major, easterly trending folds in Emm Bay and Peninsula Bay are the result of the second phase of deformation (Osadetz 1979). Kaye (1981) proposed several fold axes trending easterly through the southern portion of Kakagi Lake. During the course of mapping, in 1984 and 1985, the author has found many opposing stratigraphic top directions in this area and the placement of major fold axis could not be done with any degree of accuracy. There is also much faulting in this area that has disrupted the stratigraphy thereby making the correlation of units difficult.

The South Narrow Lake syncline (Kaye 1981) can be traced, based on stratigraphic symmetry, into the Sabaskong Batholith (Figure 1).

ECONOMIC GEOLOGY

The economic geology of the study area has been briefly discussed by Johns (1984) and will not be reiterated here. The highly faulted and sheared area in southern Kakagi Lake east of Chase Point should be re-examined for its gold potential. The gold occurrences in Lake of the Woods around Yellow Girl Bay (Blackburn 1981) indicate that the Pipestone-Cameron Fault in that area should be examined for gold. Gold showings in the Snake Bay formation west of Kakagi Lake are associated with pyritiferous shear zones (M. Hailstone, Resource Geologist, Ministry of Northern Affairs and Mines, Kenora, personal communication, 1985) and should be examined in detail.

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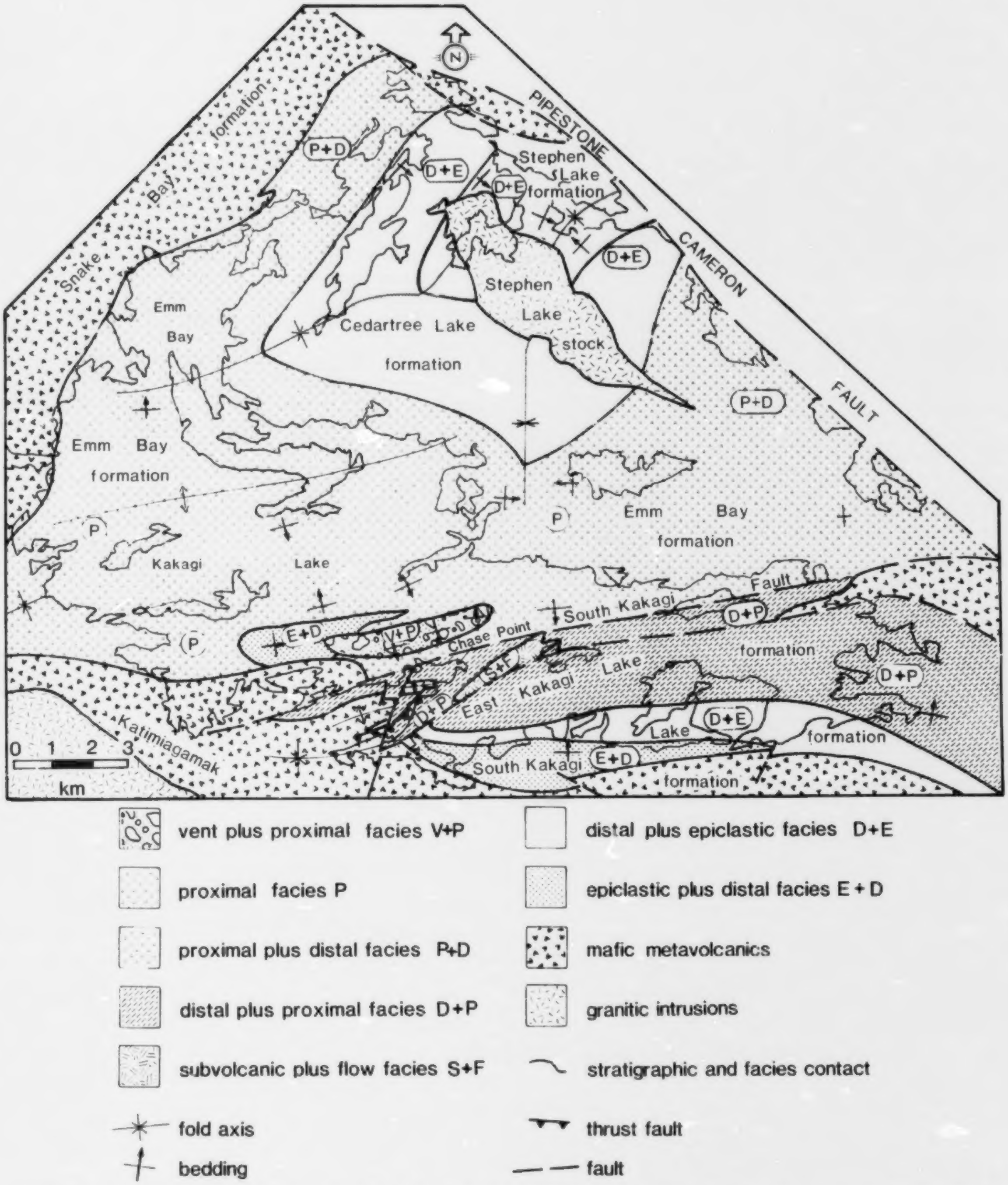
N
Snake Bay formation
PIPESTONE CAMERON FAULT
P+D
D+E
D+E
Stephen Lake formation
D+E
Stephen Lake stock
Emm Bay
Cedartree Lake formation
P+D
Emm Bay formation
P
P
Emm Bay formation
Kakagi
Lake
P
South Kakagi Fault
E+D
V+P
D+P
Chase Point
D+P
formation
S+F
East Kakagi Lake
D+P
D+P
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Lake
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Katimiagamak
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distal plus proximal facies D+P
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distal plus epiclastic facies D+E
epiclastic plus distal facies E+D
mafic metavolcanics
granitic intrusions
stratigraphic and facies contact
thrust fault
fault

***Figure 2.** Stratigraphy, volcanic facies and structure of the Kakagi Lake group of pyroclastic rocks (see Table 1.) (Project 7.)*

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8. Geology of the Lac des Iles Complex, District of Thunder Bay

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INTRODUCTION

This project is the second year of an investigation of ultramafic and mafic intrusions in the Wabigoon Subprovince. This summary reports on the geology of the Lac des Iles Complex located in the Wabigoon Subprovince, 80 km northwest of Thunder Bay. The complex, which consists of several intrusive phases ranging in composition from peridotite to gabbro, is host to significant palladium-platinum mineralization.

Lac des Iles, which provides access to most of the intrusive complex, is accessible by Great Lakes Pulp and Paper Company logging roads in the Dog River area. A short portage connects the western end of the southwest arm of Lac des Iles to a logging road. Alternatively, Lac des Iles and Camp Lake are accessible by float equipped aircraft which can be chartered at Shebandowan.

A winter road from the southern shore of Lac des Iles to Highway 527 in the east, used for transporting diamond drilling equipment to the deposit south of Lac des Iles, is now partly overgrown but can be used as a foot trail.

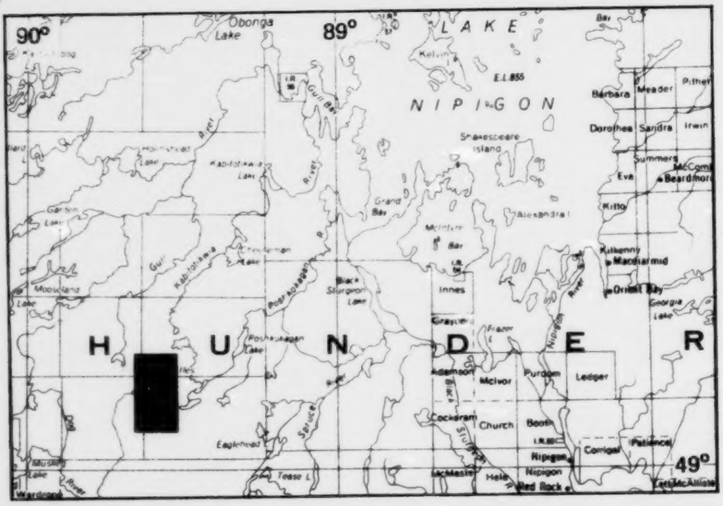
Mapping during this field season has shown that the Lac des Iles Complex developed by processes of multiple magma emplacement and *in situ* fractionation. The complex has similarities to Alaskan-type, zoned, ultramafic intrusions. Platinum group elements, copper, and nickel mineralization occurs largely as a stratiform layer within gabbroic rocks, but appears to have been redistributed by fluids associated with discordant pegmatites and intrusion breccia zones. Mapping of the complex and surrounding granitoid rocks indicates that mafic and ultramafic magmatism is probably coeval with granitoid magmatism.

MINERAL EXPLORATION

Economic interest in the Lac des Iles area began in the late 1950s and the complex has been explored for copper, nickel, and platinum group elements (PGE) mineralization. Work by Texasgulf Canada Limited and Boston Bay Mines Limited in gabbroic rocks south of Lac des Iles has revealed a deposit of 35 000 tonnes per vertical metre, grading 5.75 grams per tonne PGE, 0.62 gram per tonne gold, and 0.2% copper-nickel (The Northern Miner, Volume 62, p.11, 1976). The Canadian Mines Handbook (1976-1977, p.314) reports an approximate tonnage of 22 500 000 tons (20 400 000 tonnes).

The information on exploration history reported here is, unless otherwise indicated, taken from the Assessment Files Research Office, Ontario Geological Survey, Toronto. In 1958, following an airborne magnetic survey, F.H. Jowsey Limited acquired a group of 80 claims within ultramafic rocks in the northern part of Lac des Iles. Several conductors indicated by an airborne electromagnetic survey of the claim group in 1958 were further investigated by ground electromagnetic and magnetic surveys and diamond drilling (5 holes for 472 m) in 1959. The work failed to indicate significant mineralization.

In 1963, W. Baker and G. Moore discovered widespread Cu-Ni mineralization and staked 175 claims in gabbroic rocks south of Lac des Iles. These claims were acquired by Gunnex Limited and investigated in 1963 and 1964 by geological mapping, ground magnetic, electromagnetic, self potential, and soil geochemical surveys. Eight mineralized zones were discovered and these were tested by 11 diamond-drill holes (1516 m) in 1964. In 1966, the property was optioned by Anaconda American Brass Limited and



LOCATION MAP **Scale: 1:1 548 000 or 1 inch to 25 miles**

an additional 13 diamond-drill holes (1900 m) were drilled. No further work was carried out.

In 1967, the Canadian Nickel Company Limited diamond drilled 3 holes (1435 m) in the northeastern part of Lac des Iles, within ultramafic rocks. Minor sulphide mineralization was reported.

In 1969 and 1970, Meridian Mining and Exploration Company Limited staked 68 claims to the north and south of the property held by Gunnex Limited. These were investigated in 1970 and 1971 by ground electromagnetic and magnetic surveys, but no further work is reported.

In 1973, K.C. Kuhner staked the mineralized zones outlined by Gunnex Limited. In 1974, Boston Bay Mines Limited acquired the property and diamond drilled 35 holes in the mineralized zone (Dunning 1979). Logs for 4 drillholes (487 m) were submitted to the assessment files. Texasgulf Canada Limited optioned the property in 1975, and in 1975 to 1976 carried out airborne magnetic and electromagnetic surveys, ground geophysical surveys, geological mapping, and diamond drilling. 119 diamond-drill holes (approximately 19 030 m) were drilled. This work outlined a zone of platinum-palladium mineralization named the Roby zone, and tested other occurrences in the gabbro. Texasgulf Canada Limited dropped the property in mid 1976.

Boston Bay Mines Limited drilled 1 diamond-drill hole to investigate the vertical extent of mineralization in 1976. Significant platinum group element values were encountered from 332 m to 445 m (Dunning 1979). The mineralized zone is currently held by Boston Bay Mines Limited.

GENERAL GEOLOGY

The initial mapping of the Lac des Iles complex was by Pye (1968), at which time the extent of the complex was determined. Guarnera (1967), Dunning (1979), and Watkinson and Dunning (1979) studied aspects of the petrology of the complex with emphasis on the relationship of the gabbroic rocks to mineralization. A study of the platinum group minerals has been made by Cabri and Laflamme (1979). Recently, Talkington and Watkinson (1984) reported on the distribution of platinum group elements in rocks of the Roby zone.

The Lac des Iles Complex consists of an ultramafic intrusion centered on Lac des Iles and a gabbroic intrusion south of the lake (Figure 1) (Pye 1968, Dunning 1979). The present work suggests that the mafic and ultramafic rocks are intruded into gneissic tonalitic granitoids. A younger series of granitoid rocks, however, locally intrudes mafic and ultramafic rocks of the complex and this supports an Early Precambrian (Archean) age for the complex. No radiometric ages have been determined for these rocks to date, however, U-Pb zircon dating is currently in progress at the Royal Ontario Museum.

The ultramafic intrusion is composed of two coalescing centres, each of which consist of several intrusive phases. The centres are defined by the distribution of lithologies and attitudes of layering. The lithologic sequence of early peridotitic rocks, followed by clinopyroxenite, and finally by late websterite and gabbronorite, suggests that the ultramafic rocks follow a crystallization sequence of olivine, olivine-clinopyroxene, clinopyroxene, clinopyroxene-orthopyroxene, and finally clinopyroxene-ortho pyroxene-plagioclase. Inclusions of gabbro in the ultramafic rocks suggests that the ultramafics were intruded after the gabbro intrusion south of Lac des Iles.

The northern ultramafic centre is nearly circular in plan, with a diameter of approximately 4 km, and consists of dunite and wehrlite (olivine cumulates), olivine-clinopyroxenite, and clinopyroxenite (olivine-clinopyroxene and clinopyroxene cumulates), and websterite (orthopyroxene-clinopyroxene cumulates).

These lithologies occur in several cycles which probably represent fractional crystallization of separate pulses of magma in the chamber. Olivine cumulates occur primarily around the perimeter of the structure and the rocks become progressively more pyroxene-rich toward the core. Attitudes of layering suggest that the northern centre has an upright funnel shaped form. This structure however, is complicated by a later discordant clinopyroxenite phase in the extreme northwestern part of the intrusion, and by the discordant websterite core. Breccia zones of serpentinite with angular pyroxenite fragments are another minor discordant feature in the northern centre.

The southern ultramafic centre is elliptical in plan, with an irregular wehrlite core centred on the South East Angle of Lac des Iles. The wehrlite core is surrounded by websterite which at several locations contains inclusions of wehrlite. In contrast to the northern ultramafic centre, the southern centre is predominantly composed of massive rocks, and lacks well defined igneous layering.

The ultramafic rocks generally have fresh to moderately altered pyroxenes. Olivine is usually moderately to completely altered to serpentine and magnetite, however, some fresh olivine is locally visible in hand specimen. Plagioclase is normally absent from the ultramafics, except in websterite where it is fresh. Locally, with increased plagioclase content, the websterite grades to gabbronorite. Minor chromite is reported to occur in the ultramafic rocks (Watkinson and Dunning 1979) and a thin 3 mm chromitite seam was observed by the field party in the northern part of Lac des Iles.

In the northern centre, some of the ultramafic rocks exhibit igneous layering and lamination, however, most of the rocks are massive. Where present, layering is defined by modal mineral variations, and less commonly, by grain size variation. Modal layering, due to variations in proportions of feldspar and pyroxene, olivine and clinopyroxene, and clinopyroxene and orthopyroxene, was observed. Generally the layers are several centimetres thick, and are observed to be continuous for metres to tens of metres.

On the southwestern contact of the intrusion a marginal zone of medium- to coarse-grained hornblendite, pyroxene hornblendite, and hornblende diorite is present. The diorite commonly forms the matrix of agmatitic breccia with hornblendite fragments. The contact between this unit and the granitoid rocks displays contradictory age relation-

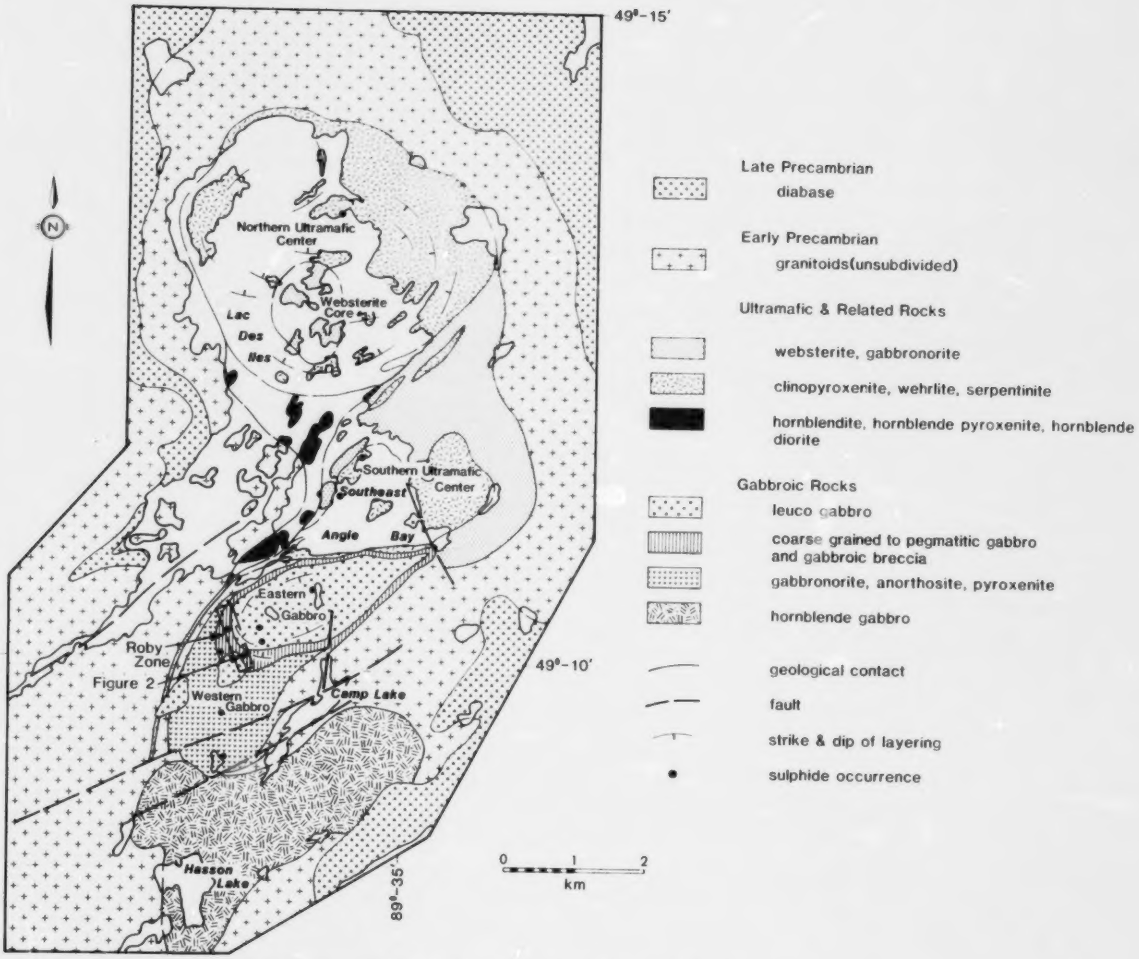

49°–15'
N
Northern Ultramafic Center
Websterite Core
Lac
Des
Iles
Southern Ultramafic Center
Southeast
Angle
Bay
Eastern Gabbro
Roby Zone
Figure 2
Western Gabbro
Camp Lake
49°–10'
Hesson Lake
89°–35'
0
1
2
km
Late Precambrian
diabase
Early Precambrian
granitoids(unsubdivided)
Ultramafic & Related Rocks
websterite, gabbronorite
clinopyroxenite, wehrlite, serpentinite
hornblendite, hornblende pyroxenite, hornblende diorite
Gabbroic Rocks
leuco gabbro
coarse grained to pegmatitic gabbro and gabbroic breccia
gabbronorite, anorthosite, pyroxenite
hornblende gabbro
geological contact
fault
strike & dip of layering
sulphide occurrence

Figure 1. Schematic geological map of the Lac des Iles Complex. (Project 8.)

ships, and therefore, the two are considered to be contemporaneous. To the east, the hornblendite appears to grade into pyroxenite.

Gabbroic rocks within the complex are primarily confined to an elliptical intrusion south of Lac des Iles. This intrusion can be subdivided into three zones. The southwestern part of the intrusion consists of predominantly medium-grained gabbronorite and has been referred to as the western gabbro by Dunning (1979). The western gabbro contains several zones of pegmatitic gabbro with grain sizes up to 2 cm which are mineralized. Toward the top of the western gabbro, in the northeastern part of this zone, minor pyroxenite and anorthosite phases are present. The northeastern part of the intrusion consists of medium-grained leucogabbro to gabbro, and is referred to as the eastern gabbro (Dunning 1979). The eastern gabbro is weakly layered due to the development of magnetite-rich layers, pyroxene-rich layers, and locally has an igneous lamination. Dunning (1979) determined that the eastern gabbro is Fe-rich, sulphide-poor, and probably not comagmatic with the western gabbro.

At the top of the western gabbro is a 60 to 300 m thick unit of heterogeneous gabbro, which contains coarse-grained to pegmatitic gabbro with sulphide mineralization. The heterogeneous unit contains numerous gabbroic phases of varying composition and texture and may be a result of mixing of the eastern and western gabbros. A representation of the heterogeneous unit is given in Figure 2, and is discussed more fully in the last section of this summary. Minor pegmatitic gabbro also occurs outside of the heterogeneous zone within the eastern and western gabbro.

The attitudes of layering within the gabbroic rocks and the concentric distribution of lithologies indicates that the intrusion has an elongated funnel

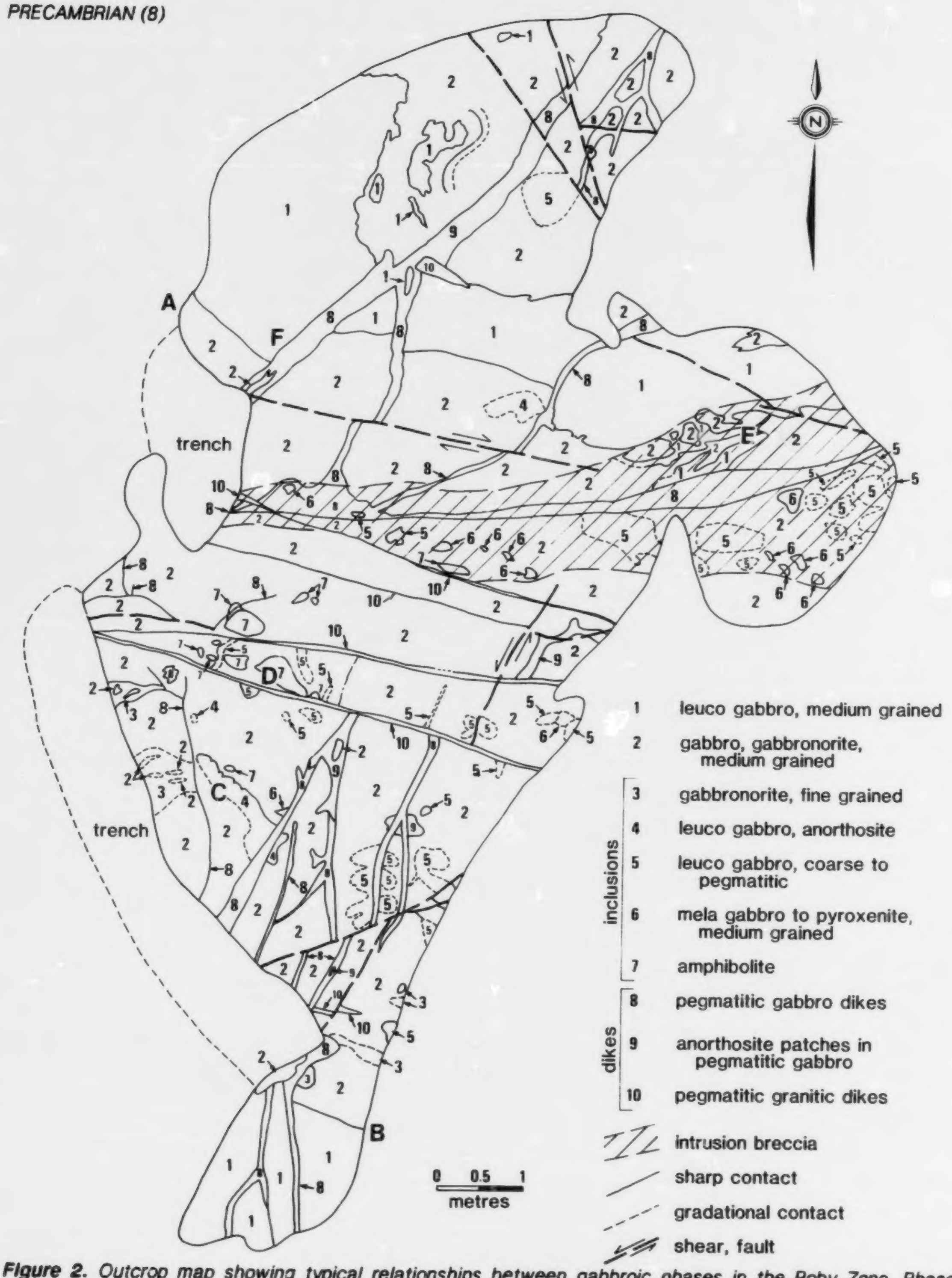

N
A
B
C
D
E
F
trench
trench
0 0.5 1
metres
1 leuco gabbro, medium grained
2 gabbro, gabbronorite, medium grained
inclusions
3 gabbronorite, fine grained
4 leuco gabbro, anorthosite
5 leuco gabbro, coarse to pegmatitic
6 mela gabbro to pyroxenite, medium grained
7 amphibolite
dikes
8 pegmatitic gabbro dikes
9 anorthosite patches in pegmatitic gabbro
10 pegmatitic granitic dikes
intrusion breccia
sharp contact
gradational contact
shear, fault

Figure 2. *Outcrop map showing typical relationships between gabbroic phases in the Roby Zone. Phase contacts at locations A and B are interpreted to be primary igneous layers. Leucogabbro inclusions at C have cuspate surfaces suggesting the inclusion was not solidified at time of incorporation. Other inclusions, such as location D, are more angular and appear to have been solid. Intermixing of gabbronorite and leucogabbro occurs at E. An intrusion breccia zone, indicated by diagonal pattern, crosscuts the igneous layering. Pegmatitic gabbro dikes core the intrusion breccia and also disrupt the layering as at location F. Field observation indicates that sulphide mineralization is associated with the pegmatitic gabbro dikes and gabbronorite. (Project 8.)*

Photo 1. Amphibolite dike intrusive into biotite tonalite showing net vein texture. The net veins are thin veins of tonalite which back-vein the amphibolite dike. This texture suggests that the tonalite was not completely solid at the time the dike was intruded. (Project 8.)

or canoe-shaped geometry. In general, the gabbroic rocks are moderately to strongly uralitized and saussuritized. The freshest rocks occur in the southern portion of the western gabbro. The gabbro is cut by several faults and numerous fractures, most of which have a sinistral offset.

In the southern part of the area northeast of Hasson Lake, hornblende gabbro is the predominant rock type. This phase is interpreted to form a separate intrusion since it is lithologically distinct and is partially separated from the western gabbro by a tonalite septum. The hornblende gabbro is medium grained, massive to weakly foliated, and is locally intruded and brecciated by quartz diorite. The hornblende gabbro and quartz diorite appear to be gradational on the southeastern side of this intrusion, to the south of Camp Lake, and the two rock types are interpreted to be co-magmatic.

West of the gabbro and outcropping on the southern shore of Lac des Iles is an approximately 50 m wide dike, which may be a feeder dike for the ultramafic rocks. The dike is composite, and is composed of medium-grained olivine gabbronorite, olivine websterite, and locally, hornblende diorite.

Granitoid rocks in the map area consist of an older suite of highly foliated to gneissic biotite tonalite, into which the Lac des Iles Complex appears to be emplaced, and a younger suite of foliated biotite and hornblende tonalite, which locally intrudes the rocks of the complex. Minor phases of hornblende-bearing quartz diorite, diorite, granodiorite, and biotite granite occur along the contact of the Lac des Iles Complex.

Fine-grained to medium-grained dike rocks ranging in composition from mafic amphibolite to diorite intrude all of the Early Precambrian lithologies of the area, including rocks of the Lac des Iles Complex. Several dikes intrude the gabbro in the vicinity of the Roby zone. One of these dikes has brecciated the gabbro, resulting in an intrusion breccia of subangular fragments of tonalite and various gabbroic rock types in a matrix of amphibolite.

Where they intrude the late biotite-hornblende tonalite, the dikes display a variety of textures suggesting that they have been emplaced during the period in which the granitoid intrusions crystallized and cooled. Some dikes have net vein textures (in which the dikes are back-veined by tonalite) (Photo 1). This suggests that the dikes were emplaced while the tonalite was above the solidus. Locally, mixing of the mafic and granitoid magma appears to have occurred, resulting in the crystallization of coarse 2 to 3 cm skeletal to blocky hornblende adjacent to the interface between the magmas (Photo 2). The presence of similar textured amphibole throughout the tonalite suggests that magma mixing may have been the mechanism of producing much of the mafic material in the granitoids.

On both a regional and local scale the Lac des Iles Complex exhibits several features characteristic of the Mesozoic Alaskan zoned ultramafic complexes (Irvine 1967; Taylor 1967). These similarities include: an association with marginal zones of hornblende-rich ultramafic rocks; the variation in rock types with complexes is due to processes of multiple magma injection and some *in situ* fractional crystallization; and the ultramafic magmas intrude, or are younger than associated altered gabbroic rocks, which are not clearly cogenetic at the exposed crustal level. The Lac des Iles Complex appears to be part of a linear zone of generally smaller, amphibole rich, ultramafic intrusions occurring near the Wabigoon-Quetico Subprovince boundary. This may represent a tectonic setting similar to the Alaskan ultramafics, which are intruded in a linear belt over 500 km long, into supracrustal rocks, after regional metamorphism and deformation, but prior to major batholith emplacement (Taylor 1967). An important difference between the Lac des Iles Complex and the Alaskan ultramafics however, is that the latter are derived from alkalic, silica undersaturated magmas and do not form orthopyroxene as a cumulus phase. The Lac des Iles complex appears to be derived from a more typical tholeiitic magma.

Relationships between the mafic dikes and the granitoid rocks suggest that mafic plutonism is coeval with granitoid magma genesis, and that magma mixing on a regional scale has occurred. One goal of future work in the area will be to further document

Photo 2. *Coarse skeletal hornblende in tonalite. Quartz and plagioclase are interstitial to the hornblende and also occur in the hollow cores of hornblende. This texture is developed along the interface between mafic and felsic phases. Skeletal crystallization of the hornblende is tentatively interpreted to be a result of supercooling due to magma mixing. (Project 8.)*

the role that the larger mafic to ultramafic intrusions, such as the Lac des Iles Complex, have in the processes of granitoid magma genesis.

ECONOMIC GEOLOGY

The exploration by Texasgulf Canada Limited and Boston Bay Mines Limited in 1975 and 1976, outlined a zone of PGE mineralization, the Roby Zone, along the contact of the eastern and western gabbro intrusions. A detailed study of the zone by Dunning (1979) and Watkinson and Dunning (1979), showed that vysotskite (Pd,Ni)S is the most abundant platinum group mineral and is associated with pentlandite and chalcopyrite. Most of the sulphide mineralization is contained within the western gabbro, where it occurs as intercumulus blebs, and less commonly, as net-textured sulphide. The sulphide mineralization is interpreted to be a magmatic phase forming from PGE, Cu, Ni, and S contained in the western gabbro liquid (Watkinson and Dunning 1979; Dunning 1979). Sulphide assemblages consisting of chalcopyrite, pyrrhotite, pentlandite, and pyrite are interpreted as being slightly metamorphosed equivalents of primary exsolution from monosulphide solid solution. Millerite and violarite are present in metamorphosed assemblages (Watkinson and Dunning 1979). Ratios of Pt/(Pt + Pd) and Cu/(Cu + Ni) were determined to be approximately 0.07 and 0.5 respectively (Watkinson and Dunning 1979). Further work by Talkington and Watkinson (1984) demonstrated that later processes involving a fluid phase have altered the primary silicates, redistributed the Cu-Ni sulphides and produced the platinum group minerals.

Field work during the present survey supports the previous conclusion that mineralization occurs near the eastern gabbro - western gabbro interface. The redistribution of sulphide mineralization may be related to the emplacement of late pegmatitic gabbro dikes and associated intrusion breccia zones.

The mineralization appears to be largely confined to the heterogeneous gabbro unit containing mineralized coarse-grained to pegmatitic gabbro. This unit appears to be conformable to the layering in the eastern gabbro, however, locally pegmatitic gabbro crosscuts the eastern gabbro, making the northern contact of the unit indefinite.

Relationships in the heterogeneous unit are complex and are typified by the outcrop map shown in Figure 2. Igneous layers, several metres thick, are defined by alternating medium-grained leucogabbro and gabbronorite layers, which resemble the eastern and western gabbro, respectively. The gabbronorite contains net-textured to interstitial sulphide. The gabbronorite layers have inclusions of leucogabbro with cuspate surfaces, suggesting that both phases may have been liquid at the time the inclusions were incorporated. Also present in the gabbronorite are inclusions of amphibolite, coarse-grained gabbro and pyroxenite. The igneous layering is crosscut and disrupted by mineralized pegmatitic gabbro dikes and by mineralized zones of intrusion breccia defined by an abundance of rounded inclusions in a matrix of altered gabbro to melagabbro. The intrusion breccias are locally cored by pegmatitic gabbro dikes, or have pegmatitic dikes emanating from them. It is suggested that these zones represent conduits in which mineralized, volatile, rich fluids were channeled.

A tentative sequence of events leading to the development of the mineralized zone, as suggested by the surface geology, is: 1) intrusion of eastern gabbro; 2) emplacement of western gabbro beneath eastern gabbro resulting in magma mixing and segregation of magmatic sulphide phase; 3) development of a pegmatitic gabbro phase at the top of the western gabbro, an increase in fluid pressure results in the intrusion of discordant pegmatitic gabbro dikes and leads to development of discordant intrusion breccia zones which redistribute sulphide mineralization formed earlier.

These conclusions suggest that the coarse-grained to pegmatitic gabbro phase, which outcrops to the east of the Roby Zone, may warrant further investigation for PGE mineralization.

During the field work up to 2% disseminated to net-textured chalcopyrite and pyrrhotite mineralization was observed within ultramafic rocks. This type of mineralization is most commonly associated with websterite and gabbronorite. There appears to have been a relatively limited investigation of the ultramafic rocks to date, and these rocks may warrant further investigation for platinum group elements. Emphasis might be placed on defining and exploring the interfaces between websterite and the more olivine- or clinopyroxene-rich lithologies, as these contacts may represent the introduction of fresh magma into the chamber, and an environment suitable for sulphide segregation.

Preliminary results from grab samples selected by the field party reveal anomalously high PGE values in sulphide-bearing websterite and gabbronorite from the ultramafic intrusion. Furthermore, the results suggest that Pt/(Pt + Pd) ratios may be substantially higher in the ultramafic rocks than in the gabbroic rocks of the Roby Zone, and that PGE values do not necessarily correlate with the amount of sulphide present. Selected samples with significant PGE and base-metal values include: a gabbronorite with approximately 1% chalcopyrite and pyrrhotite from the peninsula on the northeastern shore of Lac des Iles (870 ppb Pt, 1170 ppb Pd, 360 ppb Au, 2310 ppm Cu, 1130 ppm Ni); a websterite with up to 2% net-textured pyrrhotite and chalcopyrite from a small island in Southeast Angle Bay of Lac des Iles (170 ppb Pt, 770 ppb Pd, 25 ppb Au, 1520 ppm Cu, 1840 ppm Ni); and a peridotite with traces of pyrrhotite and chalcopyrite from the large island in Southeast Angle Bay (315 ppb Pt, 1270 ppb Pd, 95 ppb Au, 1270 ppm Cu, 1560 ppm Ni). These locations are indicated as sulphide occurrences in Figure 1. All analyses are by the Geoscience Laboratory, Ontario Geological Survey, Toronto.

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9. Atikokan-Lakehead Compilation Project

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INTRODUCTION

This project will produce a new edition of the Atikokan-Lakehead compilation map, first produced by the Ontario Department of Mines in 1966 (Pye and Fenwick 1964). The revision will incorporate approximately three seasons of field work. Reports issued in this series (Thurston 1983, 1984) describe results from the 1983 field season. A compilation produced by C.R. Kustra and John Scott of the Thunder Bay Resident Geologist's Office in the early 1970s will be issued shortly as a preliminary map to provide a partial update on the geology of part of the map area. Recently, the compilation sheets have been changed to a metric NTS based system, at a scale of 1:250 000. This has changed the boundaries of the map sheet to Latitudes US border to 50°00'N, and Longitudes 88°00'W to 92°00'W. The area is traversed by Routes 11 and 17 of the Trans Canada Highway, lumber roads within the Matawin limit of Great Lakes Paper Company which proceed west and north from Marks Township, and numerous concession roads near Thunder Bay.

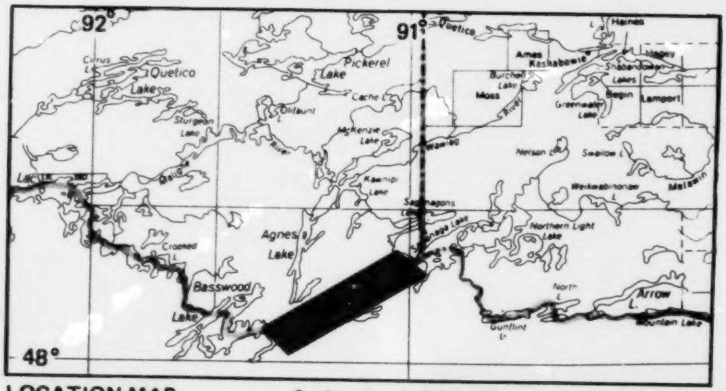
MINERAL EXPLORATION

Recent mineral exploration has concentrated in areas of Early Precambrian (Archean) rocks. Numerous exploration programs for base metal massive sulphide deposits were carried out, mainly in the 1950s and 1960s. Producers include the North Coldstream Mine at Burchell Lake and three orebodies in the Sturgeon Lake area. Iron ore was produced in the Atikokan area between the 1940s and the early 1980s from Archean ironstone of the Wabigoon Subprovince. Intense iron exploration of Archean and Timiskaming sequences in the Abitibi Subprovince occurred west of Thunder Bay in the early part of this century. Gold exploration has occurred in the Archean greenstone belts and associated intrusions since the early 20th century, with a notable early period of exploration in the 1870s and 1880s. Production has occurred from deposits in the Moss Lake, Atikokan, Lake Shebandowan, and Thunder Bay areas. Chrome was produced from the Chrome Lake intrusion east of Obonga Lake in the 1920s. A deposit of platinum group elements and copper-nickel occurs in Late Archean ultramafic intrusions of the Lac des Iles Complex (Sutcliffe, this volume; MacDonald, this volume). Copper-nickel deposits with substantial marginal grades have been described at the Great Lakes Nickel Limited deposit within the Proterozoic south of Thunder Bay.

High level granitic rocks east of Thunder Bay are host to several amethyst mines. Similar rocks west of Thunder Bay include occurrences of fluorite and molybdenite. Vein deposits of silver in Proterozoic rocks east and southwest of Thunder Bay were mined as early as the 1870s providing an impetus for development of settlement in the Thunder Bay area. Several iron occurrences within the Proterozoic Gunflint Formation have been explored. Occurrences of asbestos, fluorite, pegmatite with associated rare metals (lithium, cesium, rare earths, tantalum-niobium), gold, silver, uranium, iron, and chromium are known within the map area.

GENERAL GEOLOGY

Bedrock in the area ranges from Early Precambrian (Archean) age to Late Precambrian (Proterozoic) age. Parts of the Abitibi (Wawa-Shebandowan), Quetico, and Wabigoon Subprovinces occur in the map area. Field work this season was concentrated in the Abitibi Subprovince. The Subprovince in this area consists of parts of two mafic to felsic volcanic cycles, forming a homoclinal south-facing sequence in MacGregor Township (Scott, this volume), the eastern limit of this project (Figure 2). Progressing west from MacGregor Township the felsic top of the younger cycle is removed by intrusion of later granitoid units. The older cycle, preserved as a south-facing sequence, is folded about a southeast-trending anticlinorium centred on Conmee Township (Carter, this volume), and continues to the Shebandowan Lake area west of Thunder Bay (Figure 1). In the Shebandowan area, felsic metavolcanics of the lower cycle persist across Hagey and Begin Township, around the northern end of the Greenwater Lake Pluton and continue, as intermediate to felsic pyroclastics, to the west and southwest of Squeers Lake. The felsic se-



LOCATION MAP Scale : 1 : 1 548 000 or 1 inch to 25 miles

quence around and southwest of Burchell Lake may represent another older mafic to felsic volcanic cycle. Given the above described regional scale correlations in the metavolcanic units, it is now possible to describe regional scale facies variation using the criteria of Easton and Johns (in press). The lower mafic unit is for the most part a monotonous sequence of pillowed flows which, based upon colour index, pillow size, and form, is tholeiitic basalt. In the Lake Shebandowan area, the sequence has evolved upward into andesitic plagioclase-phyric flows. The lower felsic unit consists, from the base upward, of thin bedded dacitic tuffs representing a distal depositional facies, a felsic volcanic centre (central to proximal facies) with a quartz feldspar porphyry dome, and massive to brecciated felsic flows in the Mokomon Lake through to eastern Conmee Township area, surmounted in southern Conmee Township by intermediate pumiceous ash flows. Felsic flows, proximal flows, flow breccias and felsic hyaclastite were found in the Adrian Township area (Thurston 1983) and in the area of the Jalna property in southeastern Duckworth Township (described in detail by Chorlton and Brown 1984; Chorlton, this volume). Distal facies poorly graded monolithic felsic tuff-breccia and tuffaceous ash flows occur in northern Begin Township as units a few tens of metres thick. In the Burchell Lake area, tectonized remnants of proximal facies felsic flow breccia are succeeded upwards and outwards by massive monolithic unbedded poorly graded crystal-rich rhyolitic ash flows. Gradation from lithic fragment-rich (5%) bases upward through increasingly pumiceous upward parts has established the southeast-facing direction of the units. These units represent a proximal to distal depositional facies. Interrelated with the felsic top of the lower cycle principally in Conmee (Carter, this volume) and Horne (Carter 1984) Townships are thin (tens of metres) peridotitic komatiite flows with spinifex texture. Occurrences in the Thunder Lake area extend to the Peridotite Lake area. New occurrences noted in this survey are northwest of Stephens Lake in Adrian Township. The basaltic base of the upper cycle in the Begin Township area includes numerous peridotitic komatiite flows exposed along the Otto Lake Road (Great Lakes Paper Company Road) southwest of the Shebandowan Mine of Inco Limited, specifically just north of Horseshoe Lake and about 3 km west southwest of the Inco Mine.

The felsic top of the upper cycles is exposed only in MacGregor Township where it consists of intensely welded pumiceous lapilli-tuff which, on the basis of the vertical succession of primary structures, presence of pumice, and development of welding and silicification, is considered a subaerially deposited welded ash flow (for comparison *see* Thurston 1980).

The felsic flows and their hydrofractured nature in the Jalna deposit area (L. Chorlton, Geologist, Ontario Geological Survey, Toronto, personal communication, 1985) suggest the southeastern part of Duckworth Township is also proximal facies flows. The progression upward from rhyolitic to dacitic ignimbrites and the presence of lithic clasts in these units in the Hermia Lake area (south of Burchell Lake) in contrast to the uniformly felsic, lithic clast-rich and pumice-poor nature of ignimbrites on Highway 11 northeast of Burchell Lake suggest the former area is proximal relative to the latter. A mixed sequence of metavolcanics and metasediments cut across the strike of volcanic units considered on a lithologic basis to be Keewatin type. The crosscutting relationship suggests an unconformity similar to that between type Keewatin and Seine exposures to the west (Poulsen 1984) where these terms were defined (Lawson 1885). The unconformable relationship between the mixed sequence and the Keewatin metavolcanics, the presence of trachytic textured high-potassium metavolcanics and fluviatile sediments (Shegelski 1980) suggest the mixed unit can be considered analogous to the Timiskaming in the type area (Cooke and Moorhouse 1969). In detail, the "Timiskaming" consists of a basal conglomerate overlain by arkose, wacke, and minor mudstone in the Shebandowan area. Considered regionally, however, the Timiskaming sequence is an intercalated volcanic-sedimentary sequence. The volcanic sequence includes hornblende and rarely plagioclase-phyric basalts and andesites which occur as scoriaceous lapilli and blocks forming monolithic units several hundreds of metres thick with individual fragments variably hematized. Quartz-filled amygdules are present in Oliver Township and scattered areas elsewhere. The brecciated scoriaceous aspect and absence of pillows suggest the andesitic-basaltic unit was deposited subaerially (c.f. Giles and Hallberg 1982). The intercalation of flows and pyroclastics and form of the units suggest deposition in a stratovolcano. The volcano contained proximal mafic and felsic flows grading laterally to debris flows and fluvial conglomerates and fine sediments with mudcracks and so on. This relationship is evident in a regional sense along Highway 102 in the Intola area west of Thunder Bay where well preserved plagioclase-phyric dacitic ash flows cap the sequence. Rhyolitic debris flows and fluvial conglomerates occur beneath the ash flow. Ironstone units occur within the Timiskaming sequence, particularly in Duckworth, Horne, and Conmee Townships. Facies variation in the Timiskaming units suggest a stratovolcano in the Kaministiquia area with progressively more distal deposits eastward toward the "Timiskaming" wedge in Gorham Township. This wedge is largely conglomerates with occasional thin bedded felsic tuffs intercalated. The eastern end of Lake Shebandowan is postulated to represent another proximal area within the "Timiskaming" with an increasing proportion of fine grained sediments to the east in the Finmark area. Heterolithic volcanic breccia to tuff-breccia containing abundant trachytic clasts occurs in the Moss Township area to the west (Chorlton, this volume) suggestive of distal conditions relative to a volcanic centre at Shebandowan.

The granitoid rocks of this part of the compilation project, the Sunbar-Batwing Complex (Schwerdtner and Goodwin 1977) as reported by Percival (1983), consists of: (1) hornblende-plagioclase amphibolite and mafic gneiss; (2) tonalite to granodiorite gneiss; (3) foliated plutonic rocks, and (4) leucocratic granite, granodiorite, and syenite. The hornblende-plagioclase amphibolite and mafic gneiss are in effect inclusion trains on a metre to kilometre scale on the margins of

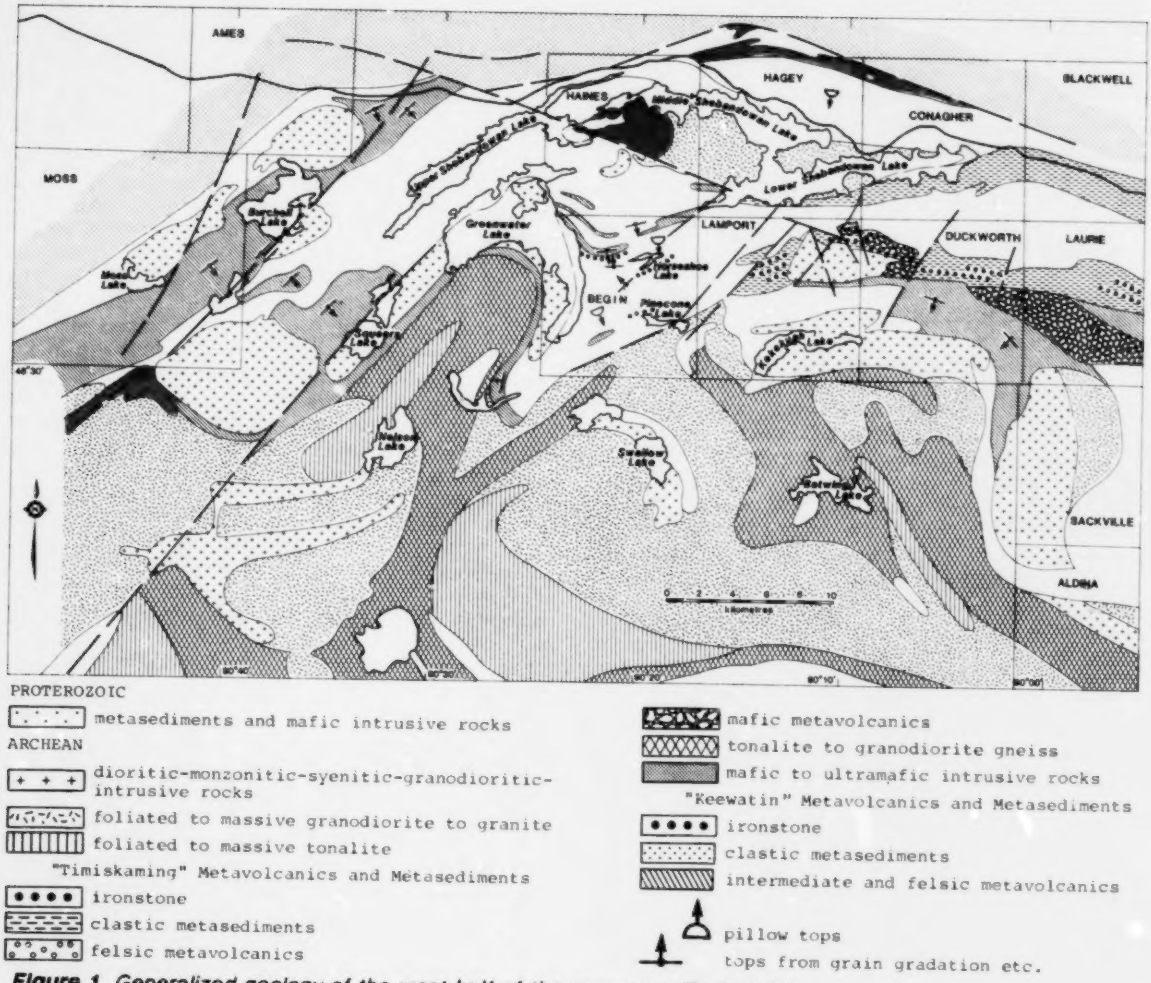

AMES
MOSS
HAINES
HAGEY
BLACKWELL
CONAGHER
Middle Shebandowan Lake
Upper Shebandowan Lake
Lower Shebandowan Lake
Burchell Lake
Moss Lake
Greenwater Lake
LAMPORT
DUCKWORTH
LAURIE
BEGIN
Horseshoe Lake
Pinecone Lake
Kekekuab Lake
Squeers Lake
Nelson Lake
Swallow Lake
Batwing Lake
SACKVILLE
ALDINA
48°30'
90°40'
90°30'
90°20'
90°10'
90°00'
0 2 4 6 8 10
kilometres
PROTEROZOIC
metasediments and mafic intrusive rocks
ARCHEAN
dioritic-monzonitic-syenitic-granodioritic-intrusive rocks
foliated to massive granodiorite to granite
foliated to massive tonalite
"Timiskaming" Metavolcanics and Metasediments
ironstone
clastic metasediments
felsic metavolcanics
mafic metavolcanics
tonalite to granodiorite gneiss
mafic to ultramafic intrusive rocks
"Keewatin" Metavolcanics and Metasediments
ironstone
clastic metasediments
intermediate and felsic metavolcanics
pillow tops
tops from grain gradation etc.

***Figure 1.** Generalized geology of the west half of the map area. (Project 9.)*

volcanic belts, for example in and west of Aldina and Sackville Townships. The inclusion trains are within the units of tonalite to granodiorite gneiss and, as such are not shown on Figures 1 and 2. The oldest granitoids in the area are tonalite to granodiorite gneiss, a foliated to gneissic unit with amphibolite and metasedimentary inclusions. Major occurrences are south of Greenwater Lake, in the Batwing Lake area, in the area of Marks and O'Connor Township. Percival (1983) described a complete textural gradation from foliated tonalite gneiss to massive tonalite south of the map area. Foliated to massive granodiorite to granite forms plutons intrusive into the early foliated tonalites and gneisses. Circular diorite-monzonite-syenite stocks and plugs form the last intrusive event represented by the Kekekuab Lake Pluton, the Peewatai Lake Pluton, the Greenwater Lake Pluton, the Burchell Lake Pluton, the Moss Lake Syenite, and the Kivikoski Syenite. Numerous small stocks piercing the supracrustal belt represent this event as well. The region is cut by numerous unmetamorphosed diabase dikes with a variety of trends.

STRUCTURAL GEOLOGY

Facing criteria consisting of pillows, normal grading of lithic fragments, reverse grading of pumice fragments, mineralogical and gross compositional zoning in various pyroclastics and metasediments have been used to determine younging direction in the greenstone belt. At the eastern end of the belt, the sequence faces south. To the west in the Conmee Township area, the Abitibi Subprovince sequence is folded about a southeast-plunging anticlinorium. Top determinations in the Duckworth-Begin Township area are variable. Stratigraphic variation progressing from

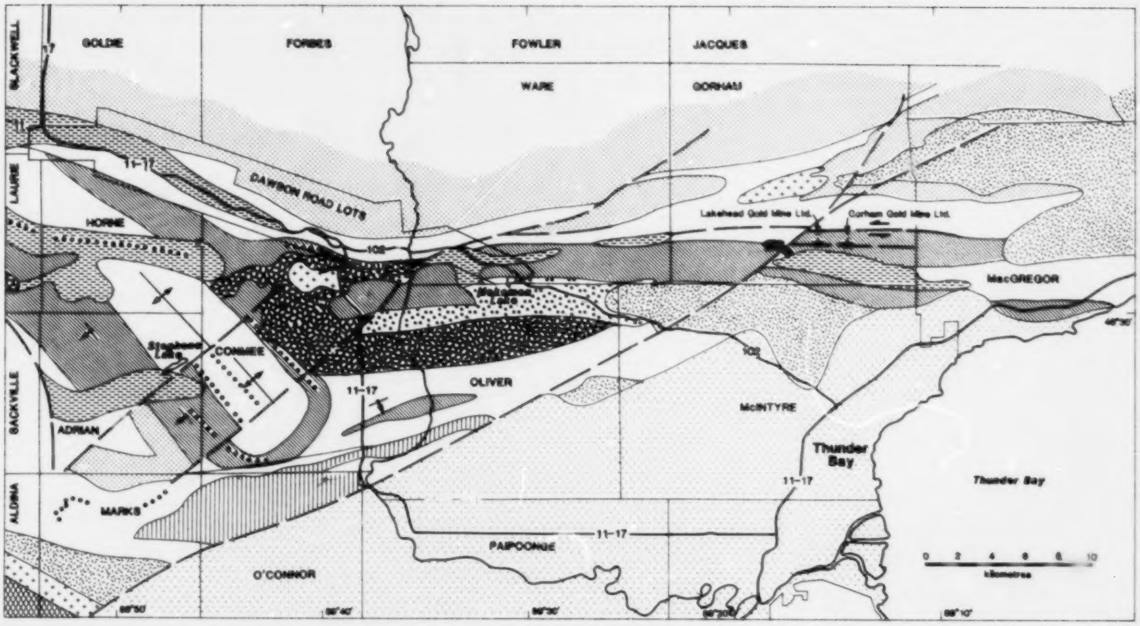


Figure 2. *Generalized geology of the east half of the map area. (Project 9.)*

tholeiites in the south through andesitic flows and felsic pyroclastics to tholeiites and komatiites with minor felsic to intermediate pyroclastics in southern Begin Township suggest overall southward younging. Many of the top reversals (Hodgkinson 1968; Stott 1985) are probably due to small scale folding and faulting (G.M. Stott, Geologist, Ontario Geological Survey, Toronto, personal communication, 1985). Therefore, the felsic metavolcanics in north-central Begin Township probably represent felsic activity associated with the top of the lower cycle. Felsic to intermediate coarse distal to re-deposited facies pyroclastics are then folded about the Greenwater Lake Pluton.

From these relations, the author infers that folds such as the Conmee Township anticlinorium represent a first folding. Stott (1985) suggested warping about the Greenwater Lake Pluton represents a second deformation. Stott and Schneiders (1983) suggested the following sequence of events.

FAULTING

The northern boundary of the Wawa (Abitibi) Subprovince is the west-trending Quetico fault. Bau (1975, 1979) suggested a dextral sense of shear on the Quetico fault was developed during D_2. Bau considered the earlier northeast to north-trending sinistral faults and later dextral northwest to west-trending faults to be a conjugate set. The faults within the first group include the Knife Lake fault which extends northeast from Knife Lake on the US border along the eastern shore of Burchell Lake and the comparable feature west of Greenwater Lake. The fault extending from Oliver Township to the Onion Lake area north of Thunder Bay is part of this system and termed the Oliver fault. The west to northwest-trending dextral faults include the Crayfish Creek fault and the Postans fault. East-trending zones of faulting in the eastern part of Lake Shebandowan are attributed to emplacement of the Shebandowan Stock (Morin 1970).

An east-trending splay of the Oliver fault extends through the wedge of "Timiskaming" rocks of Gorham Township.

A dextral sense of movement was observed on a west-trending fault zone with associated sulphide facies ironstone in Begin Township. Sinistral sense of movement was observed on the Kaministiquia fault by virtue of deformation of ironstone units.

Clast provenance and the distribution of coarse conglomeratic fluviatile sediments suggest the Timiskaming sediments, while representing a distal facies relative to the central volcanic complex, were in part derived by deposition of locally derived clasts into fault-bounded troughs.

Geochronological work has established an absolute age framework for many of the volcanic, plutonic, and structural events in the map area (Corfu and Stott 1985) using the U-Pb zircon technique. A minimum age of 2732 +10 -2 Ma for felsic metavolcanics north of Middle Shebandowan Lake dates the early volcanism. D_1 preceded or coincided with intrusion of the Shebandowan Lake pluton dated at 2696.1 ± 2.4 -2.3 Ma. This pluton predates "Timiskaming" volcanism which was dated using a sample of quartz-phyric trondhjemite clast from a conglomerate which yielded a maximum age of 2704 +1.8 -1.6 Ma. Geological relations indicate the "Timiskaming" volcanism postdates intrusion of the Shebandowan Lake Pluton. All of the above have been affected by D_2, whereas the Burchell Lake Pluton, an undeformed circular granite to trondhjemite

TABLE 1. TECTONIC SEQUENCE OF EVENTS (AFTER STOTT AND SCHNEIDERS 1983). (PROJECT 09).

Tectonic Event	
D_3 - E-W Compression	- kink folding and extension approx. perpendicular to D_2 cleavage - possible quartz veining along cleavage during extension
D_2 - Regional N-S and NW-SE compression with significant simple shear component (probably dominantly left lateral sense) - D_2 superimposed on D_1 within domains - D_2 dominant in N. half of belt and in structurally less competent groups of sediments and pyroclastic rocks; including Quetico subprovince	- quartz veins associated with late plutons (eg. Gold Creek occurrence) - late felsic plutons and hematitic fine grained dikes - Quartz veining - Quartz-carbonate veins infill along D_2 cleavage surfaces in volcanic rocks and porphyry intrusions. Most are in or near shear zones and some are in *en echelon* array. Sequence of vein generations produced by hydraulic fracturing episodes during on-going ductile D_2 deformation
D_1 - westerly-plunging folding of supracrustal across Shebandowan belt. Record of D_1 unaffected by D_2, is preserved in southern half of belt	- sedimentation - red bed deposits, conglomerates - Shebandowan stock intrusion over a protracted period - "Timiskaming" K-rich pyroclastic volcanism
-major period of volcanism	

body yields an age based on zircon and titanite of 2684 +10 -7 Ma (Table 1).

SUGGESTIONS TO PROSPECTORS

Centres of felsic volcanism described above warrant examination for base metal massive sulphide deposits. The Adrian Township area includes evidence of some chloritization of felsic pumiceous fragments, indicative of some hydrothermal activity. While the Jalna property in southeast Duckworth Township has been examined for gold, the nature of some of the chloritic brecciated felsic flows east of the Ternowesky zone (Chorlton 1984) may be worth checking for anomalous zinc values. Sulphide staining occurs in proximal rhyolite flows on Highway 102 in Ware Township in the Mokomon Lake area. The major commodity of current interest is gold. Recent reviews (Colvine *et al.* 1984) have suggested an association of lode gold deposits with altered metavolcanics close to or within regional scale shear zones across the Superior Province. In this part of the Abitibi (Wawa) Subprovince, north to northeast-trending faults host a number of gold occurrences (Stott and Schneiders 1983). With this in mind, the alignment of the Lakehead Gold Mine, Gorham Gold Mine, and Universal Gold Mine in Gorham Township along an east-trending lineament branching off the Oliver fault suggests a fault association for these deposits. G. Patterson (Resident Geologist, Ontario Ministry of Northern Affairs and Mines, Thunder Bay, personal communication, 1985) reported a 100 m wide zone of silicified sheared material with areas of porcellanous pyritic mylonite. Deflected foliations in the "Timiskaming" unit along the northern extension of Hilldale Road in Gorham Township suggest a sinistral sense of movement along the lineament. The area of the lineament warrants follow-up work for gold mineralization. North-trending shear zones are present in the area of the Jalna property (L. Chorlton, Geologist, Ontario Geological Survey, personal communication, 1985). Gold is associated with non-fault related sericitization according to Chorlton (*ibid.*). The northeast-trending fault inferred in central Conmee and Adrian Townships warrants further work; exploration pits with some shearing and sulphide mineralization were observed north and south of Stephens Lake in Adrian Township. A sulphide-rich sheared mafic metavolcanic boulder was noted on the Copenhagen Road one concession road south of Stepstone, probably related to sinistral offset on the east-trending fault separating mafic and felsic metavolcanics. Sheared mafic metavolcanics with quartz veining in a zone about 1 m wide trending 200° was noted on the Otto Lake Road (Great Lakes Paper Company) in Begin Township west of Pinecone Lake. West of Horseshoe Lake on the same road a 1 m wide zone of intensely crenulated graphitic sulphide facies ironstone with some quartz veining was noted. As logging activity has created numerous new exposures and improved access in this area, prospecting is warranted.

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10. Forbes and Conmee Townships, District of Thunder Bay

M.W. Carter

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INTRODUCTION

The map area comprises the southern part of the Township of Forbes, all of Conmee Township, and the portion of the Dawson Road Lots between them. It is bounded by Latitudes 48°36'N and 48°24'45"N, and Longitude 89°46'W and the western bank of Kaministiquia River, and is centred about 38 km northwest of Thunder Bay.

Highway 11-17 crosses the eastern part of the map area in a northerly direction and swings to a northwesterly direction in the northern part of the map area. Highway 102, which connects with Highway 11-17, crosses the eastern part of the region in an easterly direction. The Canadian National and Canadian Pacific Railways cross the eastern and northern parts of the map area. These highways and railways, together with township concession and side roads, the natural gas pipeline, and hydroelectric power line rights of way provide access to most of the area. The extreme west central part of the region is most easily accessible by helicopter.

An area of about 252 km^2 was mapped during the summer.

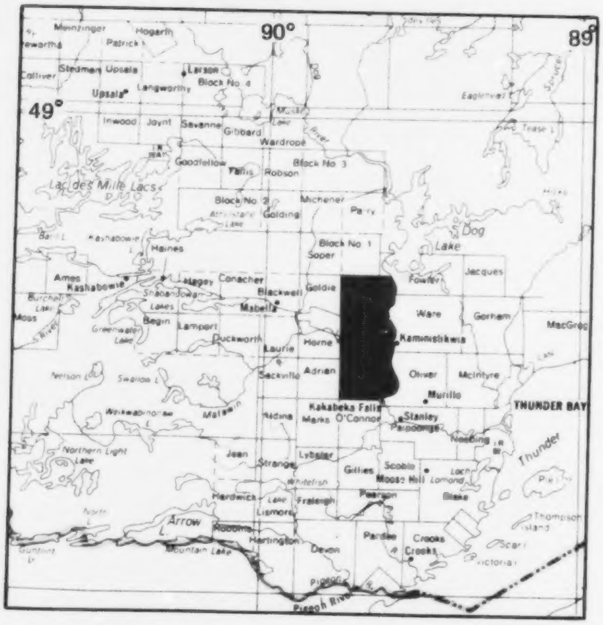
MINERAL EXPLORATION

Unless otherwise stated, the following account has been summarized from information in the files of the Resident Geologist, Ontario Ministry of Northern Affairs and Mines, Thunder Bay, and the Assessment Files Research Office, Ontario Geological Survey, Toronto.

BASE–METAL SULPHIDE MINERALIZATION AND DIAMONDS

In 1968, Acorn Mining Syndicate carried out a magnetometer survey on their property at Thunder Lake, located at the central part of the western boundary of Conmee Township, in an area underlain by ultramafic komatiitic flows, gabbro, and ironstone. This was followed in 1969 by the drilling of 3 diamond-drill holes for a total of 1204 feet (367 m) which intersected peridotite and asbestos. In the same year OJA Limited carried out ground magnetic and electromagnetic surveys to evaluate the base metal and diamond potential of the area. Several magnetic anomalies and one electromagnetic anomaly were located, but no kimberlite was found.

In 1969, Noranda Exploration Company carried out geological, airborne and ground magnetic, and electromagnetic surveys over its properties in the northwestern corner of Conmee Township, in a search for sulphide mineralization. One of these properties was underlain by gabbro and serpentinite as mapped during the current survey. Electromagnetic anomalies were discovered.



LOCATION MAP

Scale : 1 : 1 548 000
or 1 inch to 25 miles

COPPER

In the early 1920s, two pits were put down in a shear zone about 30 to 60 feet (9-18 m) wide, in mafic metavolcanics, for gold mineralization, on a property located in the Dawson Road Lots in the northwestern corner of the map area. The shear zone was subsequently explored for copper when a magnetometer survey was carried out by persons unknown, which located an anomaly about 300 feet (91 m) wide by 6600 feet (2012 m) long, to the south of the shear zone. Then in 1955 Kinasco Explorations Limited drilled a short X-ray hole for an unstated length on the zone. In 1956, Lun-Echo Gold Mines Limited drilled 17 diamond-drill holes for 2689.4 feet (820 m) along a strike length of 1100 feet (335 m) on the zone.

GOLD

Exploration for gold was carried out initially on the Lun-Echo occurrence in the Dawson Road Lots in the northwestern corner of the map area. Two pits were put down in a shear zone, as described under Copper, above.

During the summer of 1985, Noranda Exploration Company Limited had a grid cut and were carrying out geological surveying on their property in an area about 3.5 km southwest of Sunshine in Conmee Township.

Throughout the current survey, mineralized shear zones and quartz veins were grab sampled and assayed for gold and silver. The results are reported in the Economic Geology Section.

IRON

Most of the exploration in the map area was for iron deposits, the region forming the eastern end of the Matawin Iron Range.

In 1909, B.L. Morrison carried out dip-needle surveys near the middle part of the eastern boundary of Conmee Township, over a sulphide facies ironstone unit consisting of massive pyrite and pyrrhotite. This was followed in 1917 by trenching and drilling of an unknown extent by The Nicholas Chemical Company.

In 1957, magnetometer and geological surveys and the drilling of 2 diamond-drill holes for 797 feet (243 m) were carried out by the Inland Ore Company Incorporated, on an oxide facies magnetite-jasper ironstone occurrence in the extreme northeastern corner of Conmee Township.

In 1961 to 1962, Hanna Mining Company carried out ground magnetometer and geological surveys on their properties in the west-central, southern, and southwestern parts of Conmee Township to evaluate previously found aeromagnetic anomalies, which were subsequently found to be caused by oxide facies magnetite-quartz ironstone units.

In 1968, a ground magnetometer survey was carried out by Phelps-Dodge Corporation of Canada Limited at the central part of the northern boundary of Conmee Township.

MOLYBDENUM

Prior to 1925, a 50-foot (15 m) shaft was put down and 18 feet (5.5 m) of crosscutting, together with trenching and pitting, were carried out on the Lundmark molybdenite occurrence located near the southeastern corner of Conmee Township. In 1976, Noranda Exploration Company Limited carried out an induced polarization survey over the occurrence, and discovered three anomalies. In 1978, Duval International Corporation carried out ground electromagnetic, ground magnetic, and geological surveys over the occurrence. No electromagnetic anomalies were associated with the occurrence, but the magnetic survey outlined the granitoid stock associated with the deposit. Quartz veins were found intruding the granitic body.

NICKEL–COPPER

In 1967, the International Nickel Company of Canada Limited drilled 2 diamond-drill holes for 988 feet (301 m) in the northwestern part of Conmee Township, in the vicinity of Gold Lake, in serpentinite units, apparently for nickel-copper mineralization.

GENERAL GEOLOGY

The map area straddles the Abitibi (Shebandowan section) - Quetico subprovincial boundary and is underlain by Archean rocks, Figure 1, mantled by Pleistocene and Recent deposits. The area had been previously mapped by T.L. Tanton (1925).

The Archean rocks comprise Keewatin-type metavolcanics and metasediments; Quetico-type clastic metasediments; intrusive ultramafic, mafic, and felsic rocks; Timiskaming-type metavolcanics and metasediments; diabase and lamprophyre dikes, and a lamprophyric diatreme.

The Keewatin-type metavolcanics, which occur in the southern half of the Dawson Road Lots and all of Conmee Township, consist predominantly of a tightly folded sequence of subaqueous, massive and pillowed, ultramafic, mafic, intermediate, and felsic flows forming two cycles (Carter 1984). The first cycle consists of a lower sequence of mafic, pillowed, aphyric, and porphyritic tholeiitic basalts and andesites, exposed in the southern part of the Dawson Road Lots and northern Conmee Township, and an upper part of porphyritic and aphyric, dacitic and felsic flows, best exposed in central Conmee Township. The komatiitic base of the upper cycle consists of flows intercalated with the felsic top of the lower cycle, exposed in central Conmee Township in a large anticlinorium. The overlying tholeiitic metavolcanics of the upper cycle are exposed in southeastern Conmee Township. The felsic metavolcanics of the upper cycle are found in southeastern Conmee Township near the hamlet of Hume. The tholeiitic mafic to intermediate flows show massive, pillowed, vesicular, amygdaloidal, variolitic, and hyaloclastic structures, and form flows at least 100 m thick. The uppermost part of some of these flows is tuffaceous. The felsic metavolcanics consist of aphyric and porphyritic, brownish, cream, and greyish-white flows containing quartz phenocrysts. Some of the porphyritic felsic volcanic rocks have a massive

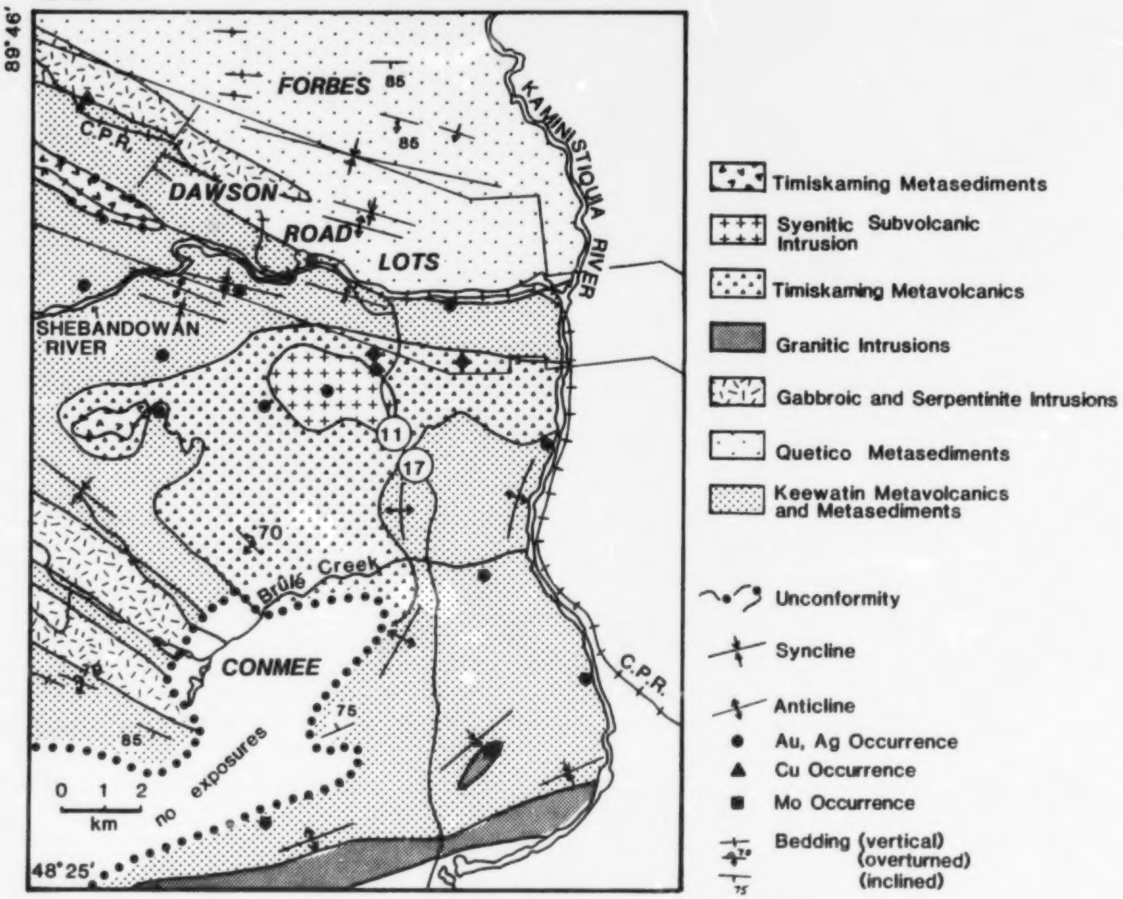

48°36'
89°46'
FORBES
DAWSON
ROAD
LOTS
C.P.R.
KAMINISTIQUIA RIVER
SHEBANDOWAN RIVER
Brûlé Creek
CONMEE
no exposures
11
17
70
75
85
0 1 2
km
48°25'
C.P.R.
Timiskaming Metasediments
Syenitic Subvolcanic Intrusion
Timiskaming Metavolcanics
Granitic Intrusions
Gabbroic and Serpentinite Intrusions
Quetico Metasediments
Keewatin Metavolcanics and Metasediments
Unconformity
Syncline
Anticline
Au, Ag Occurrence
Cu Occurrence
Mo Occurrence
Bedding (vertical)
(overturned)
(inclined)

Figure 1. Geological sketch map of Forbes and Conmee Townships. (Project 10.)

medium-grained matrix, and are believed by the author to comprise a rhyolite dome. Fragmental rocks comprise intermediate and felsic tuff, lapilli tuff, and tuff breccia. The second cycle commences with ultramafic and mafic flows, best exposed near the middle part of the western boundary of Conmee Township, where they comprise spinifex-textured, pillowed, komatiitic flows, some of which show polysuturing. These grade from a massive, olivine cumulate base to pillowed, spinifex-textured, or polysutured upper parts, and are interlayered with the intermediate and felsic part of the lower cycle. In the southwestern part of Conmee Township, the komatiitic rocks are overlain by mafic, and intermediate to felsic flows and fragmentals, forming the upper part of the second cycle.

The Keewatin-type metasediments interlayered with the metavolcanics include clastic and chemical metasediments. The clastic metasediments consist of coarse and fine-grained wackes, siltstones, and mudstones, which form units up to about 300 m thick. The wackes may contain lenses and bands of pure magnetite. The chemical metasediments comprise grey and black chert units and composite ironstone units consisting of interlayered bands of magnetite and chert, magnetite and jasper, and pyrite and chert. These ironstone units are from 0.5 to 100 m thick.

The Quetico-type metasediments occur in the northern part of the area in Forbes Township, and the northern part of the Dawson Road Lots, and consist predominantly of wackes interlayered with less abundant siltstone, mudstone, and chert. The beds in the wacke vary from about 2.5 cm to about 30 cm, and show graded bedding and vaguely defined crossbedding.

Ultramafic and mafic intrusive rocks form sills and lenses of serpentinite and gabbro, parallel to the regional trend of the enclosing metavolcanics and metasediments, in the northern half of the Dawson Road Lots and near the central part of the western boundary of Conmee Township. In this latter area the gabbros and serpentinites form sills up to about 1 km thick.

Early granitoid intrusions occur in the southern and southeastern part of the map area, where they intrude the Keewatin-type rocks, and in the northern part of the map area, where they intrude the Quetico-type metasediments. The granitoid rocks in the southern and southeastern corner of the map area form the northern margin of a batholith extending southwards beyond the southern limit of the area, and comprises massive and foliated granitic to tonalitic rocks, and a lensoid, northeasterly trending, massive and porphyritic, molybdenite-bearing, granodioritic to tonalitic stock.

Timiskaming-type metavolcanics occur in the central part of the map area, flanked by the Keewatin-type metavolcanics, and consist predominantly of hornblende-rich, grey-green and green, calc alkalic, andesitic, and dacitic pyroclastics. The volcanic rocks are believed to be subaerial because of the absence of pillowed structures and the occurrence of bright red hematized parts of the flows and pyroclastics. As well, hornblende-rich purplish, red, and pale grey alkalic trachytic pyroclastics, with minor flows of similar composition, and brown and green hornblende-feldspar porphyries occur.

Timiskaming-type metasediments consist of: an early sequence of chemical metasediments, comprising magnetite-jasper and magnetite-chert ironstone units; and a later sequence of polymictic conglomerate containing boulders and cobbles of Keewatin-type and Timiskaming-type volcanic rocks, chert, jasper, and jasper-magnetite ironstone in a grey or greenish black matrix near the west central part of the area; and wackes, siltstones, and gritty siltstones along Highway 11-17 in the northwestern part of the map area, respectively.

A late stock, consisting predominantly of massive medium-grained red hornblende-syenite with marginal facies of hornblende diorite and monzodiorite, cuts the Timiskaming volcanic rocks in the central part of the map area.

Narrow dikes, up to 50 m wide, of aphyric and porphyritic black diabase, dark green and brownish red biotite lamprophyre, and a biotite lamprophyre breccia diatreme, cut the supracrustal rocks of the map area.

The Keewatin and Timiskaming metavolcanic sequences, and the Quetico-type metasedimentary sequence have been metamorphosed to the biotite grade of the greenschist facies of regional metamorphism.

Pleistocene deposits comprise a red glaciolacustrine clay, which covers much of the northern part of the map area; ground moraine till, comprising sand and gravel, developed in the southern half of the map area; and peat and muck in large swampy areas occurring principally in the southwestern part of the region (Mollard and Mollard 1981, 1983).

The nature and distribution of the Keewatin and Timiskaming metavolcanics, observed during the current mapping program and that during the summer of 1984 in the adjoining area to the west (Carter 1984), suggest a grouping of the volcanic rocks into facies, using the criteria of Williams and MacBirney (1979, p.312-313), and Easton and Johns (in press) as shown in Figure 2. The Keewatin-type subaqueous pillow lavas of tholeiitic and komatiitic composition with associated chemical and clastic sediments, represent a proximal-distal facies, because of the preponderance of pillow lava flows, at least 100 m thick, over pyroclastics; the occurrence of lapilli tuff and tuff rather than tuff breccia; the occurrence of a possible flanking rhyolite dome in southeastern Conmee Township; and the association of these rocks with fine- to medium-grained clastic sediments showing graded bedding. The Timiskaming-type metavolcanics are considered by the author to represent a central-proximal facies because of the predominance of fragmental rocks, the coarse size of the clasts, the very poor to completely unsorted nature of the rocks which are matrix-supported, the occurrence of interlayered flows, a subvolcanic syenitic intrusion and other smaller hornblende-feldspar porphyries; and the occurrence of debris flows towards the outer part of the complex.

STRUCTURAL GEOLOGY

The Keewatin-type metavolcanic-metasedimentary rocks marginal to the central zone Timiskaming-type metavolcanics are tightly folded about curvilinear axes subconcentrically disposed around the Timiskaming-type volcanic-intrusive complex. On the northern flank of this zone the Keewatin metavolcanics are folded about northwest-trending axes, which veer to easterly in the northeastern part of the area. On the eastern flank of the central zone, the axes are northerly and northeasterly; to the southeast, the axes are northeasterly and veer through westerly in the south of the map area, to northwesterly in the southwestern part of the region. Folding in the Timiskaming was not evident, but the interlayered chemical metasediments in the southwestern part of the zone strike northwest and are overturned steeply to the southwest. The folding may be domal in this central zone. Folding in the Quetico metasedimentary sequence in the northern part of the map area is isoclinal about west-northwest axes.

Foliation is present in the Keewatin metavolcanics to the north, south, and southeast of the Timiskaming-type unit, but is best developed in the latter area. To the north, the foliation trends west-southwesterly and easterly, but trends west-northwesterly in the northwest part of this area. To the southeast, it trends northeasterly, and veers through a westerly direction in the south to a northwesterly trend in the southwest. The foliation dips steeply from 60° to 85°.

The major shear zone of the map area is the Quetico-Crayfish Creek fault system forming the Abitibi (Shebandowan section) - Quetico subprovincial boundary, which is curvilinear in the map area, striking east-northeasterly in the eastern part of the area, and northwesterly in the western part of the map area. Narrow shear zones, trending between west-northwest and west-southwest, occur throughout the Keewatin-type metavolcanic proximal-distal zone, some of which are mineralized with gold and silver.

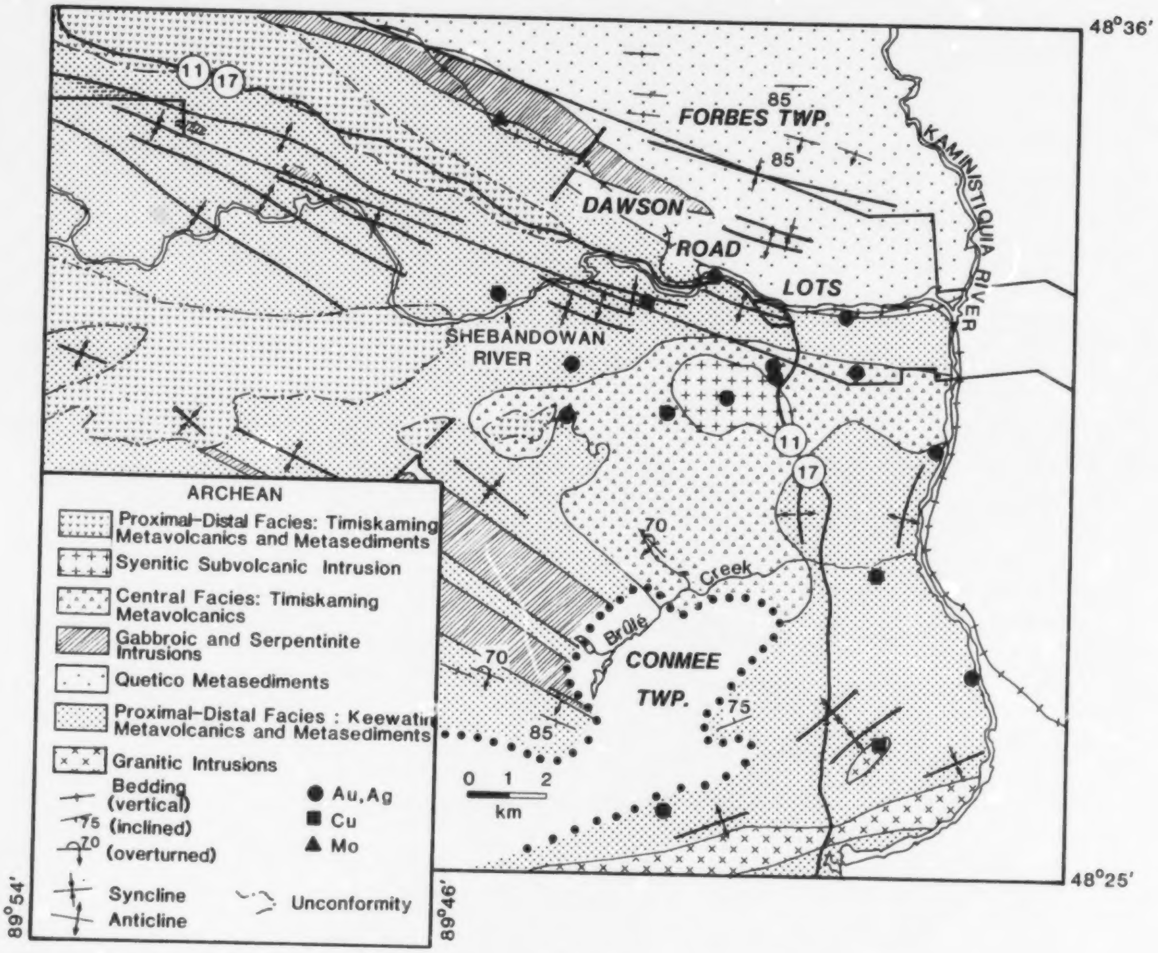

48°36'
48°25'
89°54'
89°46'
11
17
FORBES TWP.
DAWSON
ROAD
LOTS
KAMINISTIQUIA RIVER
SHEBANDOWAN RIVER
Creek
Brûlé
CONMEE TWP.
85
70
75
0 1 2
km
ARCHEAN
Proximal–Distal Facies: Timiskaming Metavolcanics and Metasediments
Syenitic Subvolcanic Intrusion
Central Facies: Timiskaming Metavolcanics
Gabbroic and Serpentinite Intrusions
Quetico Metasediments
Proximal–Distal Facies : Keewatin Metavolcanics and Metasediments
Granitic Intrusions
Bedding (vertical)
75 (inclined)
70 (overturned)
● Au, Ag
■ Cu
▲ Mo
Syncline
Anticline
Unconformity

Figure 2. *Volcanic facies map of the Goldie-Horne-Forbes-Conmee Townships area. (Project 10.)*

ECONOMIC GEOLOGY

COPPER

Assays from sampling of an unreported kind by Lun-Echo Gold Mines Limited, from a 6.0-foot (1.8 m) wide band of pyrrhotite in a shatter zone in mafic metavolcanics well mineralized with pyrrhotite, pyrite, and chalcopyrite, and located 400 m north of the hamlet of Finmark in the northwestern corner of the Dawson Road Lots, gave 2.44% copper (Resident Geologist Files, Ontario Ministry of Northern Affairs and Mines, Thunder Bay).

GOLD AND SILVER

The only reported assays carried out for gold and silver were from the drilling by Lun-Echo Gold Mines Limited, and all the results were nil or trace (Resident Geologist Files, Ontario Ministry of Northern Affairs and Mines, Thunder Bay). During the current survey, gold and silver in amounts ≥0.01 ounce per ton and 0.10 ounce per ton respectively, were obtained from assays of grab samples from 15 localities within the map area. All assays reported were done by the Geoscience Laboratories, Ontario Geological Survey, Toronto. The precious metal mineralization occurred in 4 ways:

Shear Zones

1. A grab sample, from a shear zone about 6 m wide in Keewatin mafic metavolcanics located 200 m east of the Sunshine bridge on Highway 11-17, Dawson Road Lots, and within 200 m of the shear zone forming the Abitibi-Quetico subprovincial boundary, gave 0.03 ounce gold and <0.10 ounce silver per ton.
2. A grab sample, from a graphite-quartz zone in the Abitibi-Quetico subprovincial boundary shear zone, located 300 m east of Conmee station on the Canadian National Railway track, Dawson Road Lots, yielded 0.01 ounce gold and <0.10 ounce silver per ton.
3. A grab sample, from a 0.3 m wide shear zone in a limonitic, interlayered siltstone-mudstone outcrop within the proximal-distal Keewatin metavolcanics, located 700 m south-southwest of the

mouth of Sunshine Creek, Dawson Road Lots, gave <0.01 ounce gold and 0.22 ounce silver per ton.

4. A grab sample, from a 1 m wide shear zone in Keewatin felsic metavolcanics, located on the hydroelectric transmission line 2.3 km northeast of the northeastern corner of Gold Lake, northwestern Conmee Township, yielded <0.01 ounce gold and 0.14 ounce silver, respectively, per ton.
5. A grab sample, from a 0.6 m wide shear zone in limonitic and sericitic rhyolite of the Keewatin felsic metavolcanics, located 3.2 km northeast of the northeastern corner of Gold Lake, northwestern Conmee Township, yielded 0.01 ounce gold and <0.10 ounce silver, respectively, per ton.
6. A grab sample, from a 0.3 m wide shear zone in grey limonitic Keewatin dacite located 3.1 km south-southeast of the intersection of the Finmark Road and Highway 11-17, in the northwestern corner of Conmee Township, yielded <0.01 ounce gold and 0.30 ounce silver, respectively, per ton.
7. A grab sample, from a 25 cm wide limonitized shear zone in Timiskaming andesite, on the north side of the fire lookout road, 0.7 km southeast of the fire lookout, north central Conmee Township, yielded <0.01 ounce gold and 0.42 ounce silver per ton.
8. A grab sample, from a 0.6 m wide limonitic and carbonatized shear zone in Timiskaming hornblende andesite, 0.9 km south-southwest of Sistonens Corners, northeastern Conmee Township, yielded <0.01 ounce gold and 0.11 ounce silver per ton.
9. A grab sample, from a 25 cm wide limonitic shear zone in Timiskaming andesite, 1 km south-southwest of Sistonens Corners, northeastern Conmee Township, yielded 0.01 ounce gold and 3.19 ounces silver per ton.
10. A grab sample, from a 0.3 m wide carbonatized shear zone, also in Timiskaming andesite, 1.75 km southeast of Sistonens Corners, northeastern Conmee Township, yielded <0.01 ounce gold and 0.10 ounce silver, respectively, per ton.

Ironstone Units

11. A grab sample, from fine-grained, disseminated pyrite in a magnetite-jasper ironstone unit in the Keewatin metavolcanics on the Canadian National Railway track, 2.2 km north-northeast of Mokomon Station, northeastern Conmee Township, gave 0.01 ounce gold and <0.10 ounce silver per ton.
12. A grab sample, from friable, fine-grained pyrite from a pyrite-chert ironstone unit overlying rhyolite at the Morrison occurrence in the Keewatin metavolcanics, and located 0.9 km east of Mokomon in Conmee Township, gave 0.01 ounce gold and 0.63 ounce silver per ton.

Quartz Vein

13. A grab sample, from a 23 cm wide quartz vein containing disseminated pyrite at a dacite/rhyolite contact in the Keewatin metavolcanics on the west bank of the Kaministiquia River, 2.2 km north of Hume, Conmee Township, gave 0.24 ounce gold and 0.78 ounce silver per ton.

Intermediate and Felsic Intrusive Rocks

14. A grab sample, from a pyritized syenite dike in the Timiskaming central volcanic facies, 1 km southwest of the fire lookout tower, north-central Conmee Township, yielded 0.01 ounce gold and <0.10 ounce silver per ton.
15. A grab sample, from a granite-pegmatite dike intruding a magnetite-wacke ironstone unit 0.94 km northwest of the fourth and fifth side road and Blind Line road intersection, south Conmee Township, yielded <0.01 ounce gold and 0.44 ounce silver per ton.

It is recommended that the mineralized shear zones, the quartz vein, and the mineralized ironstone units be further prospected for gold, as well as the area about 3.5 km southwest of Sunshine, where numerous narrow limonitized and pyritized shear zones were encountered during the mapping.

MOLYBDENITE

Sampling of an unreported kind of a quartz vein mineralized with molybdenite, in the granitic stock, about 2.5 km west of Hume in the southeastern corner of the map area, gave 1% to 2% MoS on assay (Assessment Files Research Office, Toronto). Further exploration for molybdenite should be restricted to this stock as no other occurrences of molybdenite were encountered in the batholith to the south and southwest.

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11. MacGregor Township, District of Thunder Bay

John Scott

Resource Geologist, Ministry of Northern Affairs and Mines, Thunder Bay.

INTRODUCTION

During the 1984 and 1985 field seasons, 90% of MacGregor Township was geologically mapped at a scale slightly larger than 1 inch to 1/4 mile (1:15 840).

MacGregor Township is situated in the Municipality of Shuniah and lies immediately northeast of the City of Thunder Bay. The map area is bounded on the south by the waters of Thunder Bay, Lake Superior, and on the north by Latitude 49°30′36″N. Longitudes 89°11′W and 88°48′W, mark the eastern and western limits of the map area, respectively.

Highway 11-17, the Trans Canada Highway, cuts across the southern portion of the township near Lake Superior; Highway 527, the Spruce River Road, traverses northward across the western sector of the township. Hydro and pipeline right of ways and bush roads provide access to more than 75% of the township. The least accessible areas are the northwestern sector away from Highway 527, and the area where Longitude 89°W intersects the northern boundary.

PREVIOUS GEOLOGICAL WORK

The northern sector of the township was mapped by MacDonald (1941). Moorhouse (1960) mapped the Proterozoic Gunflint Formation located in the southern section of the township proximal to Lake Superior. McIlwaine (1971a, 1971b, 1975) mapped McTavish Township, immediately east of the present map area. Tanton (1928) mapped parts of the northeastern sector of the area. McKellar (1874) describes some of the earliest discovered mineral occurrences of the area. Scott (1984) gave a preliminary account of the geology of the western half of the map area.

GENERAL GEOLOGY

All bedrock of the map area is Precambrian in age. Archean rocks belonging to the Abitibi (Shebandowan sector) Subprovince consist of metavolcanics and associated metasediments, mafic to ultramafic intrusions, hornblende syenite, porphyritic diorite, granite, quartz monzonite, and quartz-feldspar porphyry.

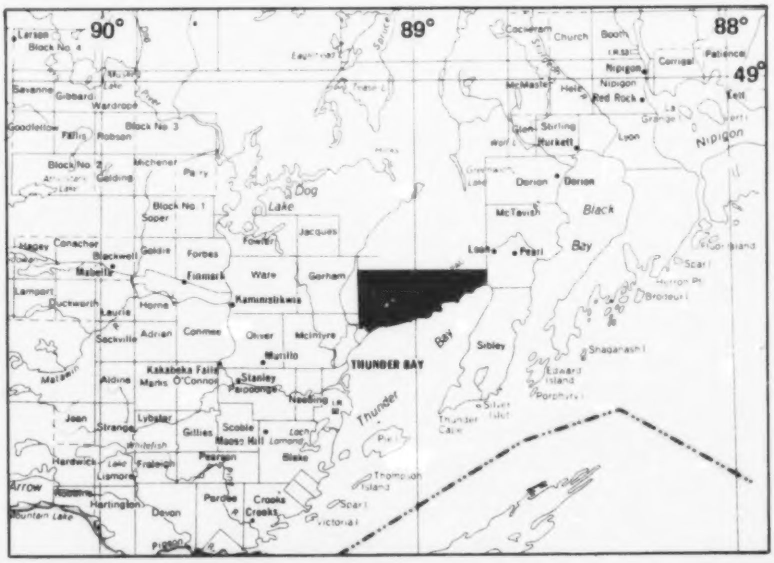
The metavolcanics have been subdivided into three major subdivisions: felsic (pyroclastics and flows), intermediate to mafic (flows), and ultramafic (flows and possibly pyroclastics).

The metavolcanics uniformly face south and form two mafic to felsic volcanic cycles.

The felsic volcanic rocks of the upper cycle trend easterly across the southern part of the map area from its west boundary to Lake Superior in the Mary Harbour area. These rocks consist mainly of pyroclastics ranging from pumiceous tuffs to tuff breccia. Clast size in the tuff breccia is up to 30 cm, but typically average less than 10 cm. Collapsed pumice fragments are readily identified on the hydro line north of Highway 11-17 and east of Highway 527.

Quartz-feldspar porphyritic stocks are also associated with these felsic volcanic rocks. Some of the stocks containing blue quartz eyes intrude the felsic metavolcanics and are best exposed along Highway 11-17 approximately 1.5 km east of the Highway 527/Highway 11-17 junction.

Intermediate to mafic metavolcanics consist of massive amphibolitic flows, amygdaloidal flows, tuffs, and tuff breccia. These rocks are situated north of the previously described felsic volcanic rocks. These rocks also disappear under Lake Superior in



LOCATION MAP Scale : 1 : 1 548 000 or 1 inch to 25 miles

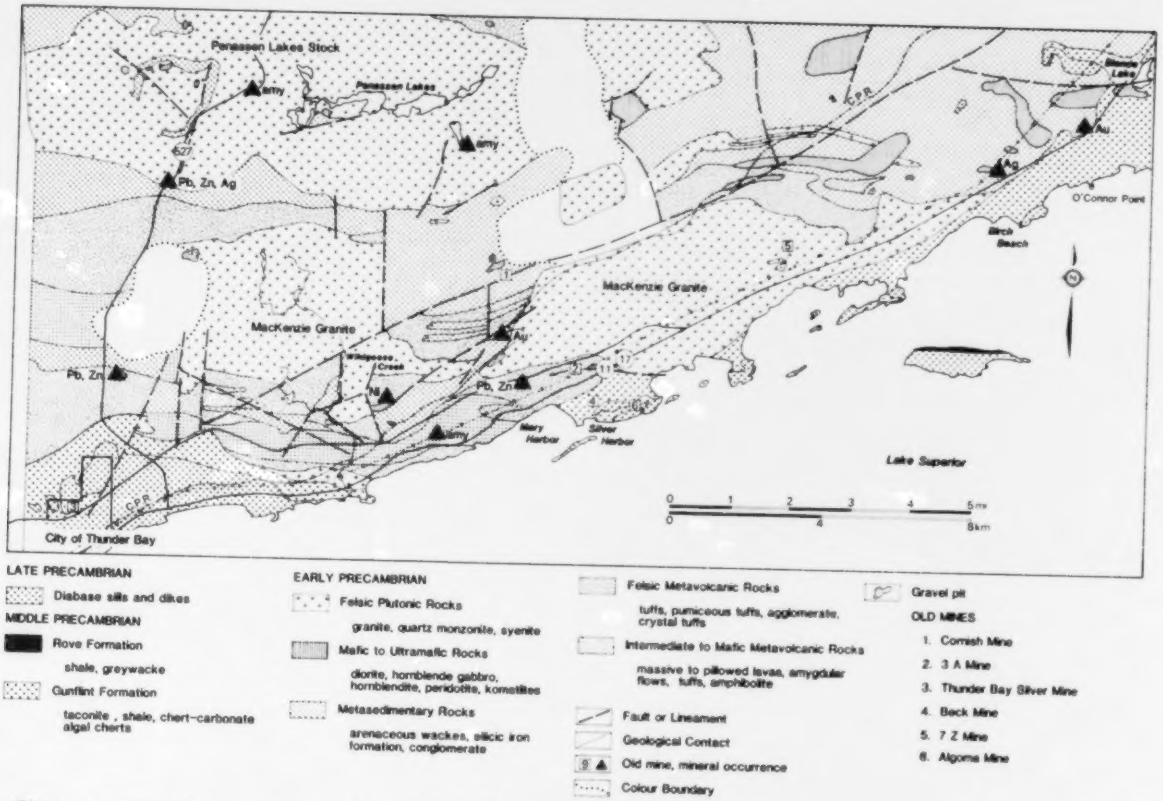

Penassen Lakes Stock
Penassen Lakes
amy
Pb, Zn, Ag
527
amy
CPR
Au
Ag
O'Connor Point
Birch Beach
N
MacKenzie Granite
MacKenzie Granite
Wildgoose Creek
Au
Pb, Zn
Ni
Pb, Zn
amy
11
17
Mary Harbor
Silver Harbor
Lake Superior
CPR
City of Thunder Bay
0 1 2 3 4 5 mi
0 4 8 km
LATE PRECAMBRIAN
Diabase sills and dikes
MIDDLE PRECAMBRIAN
Rove Formation
shale, greywacke
Gunflint Formation
taconite , shale, chert-carbonate algal cherts
EARLY PRECAMBRIAN
Felsic Plutonic Rocks
granite, quartz monzonite, syenite
Mafic to Ultramafic Rocks
diorite, hornblende gabbro, hornblendite, peridotite, komatiites
Metasedimentary Rocks
arenaceous wackes, silicic iron formation, conglomerate
Felsic Metavolcanic Rocks
tuffs, pumiceous tuffs, agglomerate, crystal tuffs
Intermediate to Mafic Metavolcanic Rocks
massive to pillowed lavas, amygdular flows, tuffs, amphibolite
Fault or Lineament
Geological Contact
9 ▲ Old mine, mineral occurrence
Colour Boundary
Gravel pit
OLD MINES
1. Cornish Mine
2. 3 A Mine
3. Thunder Bay Silver Mine
4. Beck Mine
5. 7 Z Mine
6. Algoma Mine

***Figure 1**. Generalized geology of MacGregor Township. (Project 11.)*

the Mary Harbour-Silver Harbour area. The general strike direction of both the felsic and mafic volcanic units is east-west.

Associated with the mafic volcanic rocks and in places intercalated with them, are arenaceous metawackes, plus narrow iron formation units. Iron formation is exposed only southeast of the Mount Baldy area. Clasts of the iron formation were observed in a conglomerate about 1 mile northwest of Mary Harbour, but no exposures of the iron formation were noted in that area. Where facing directions can be discerned, graded beds indicate that the rocks form a southerly facing sequence.

Several small exposures of komatiitic rocks occur along the hydro line just west of Wildgoose Creek. They have been faulted, and a wedge of granitic rock now separates the two main exposures. The easterly exposure is situated approximately 1.2 km east of Wildgoose Creek and the hydro line intersection. These rocks are fragmental in part and could represent ultramafic pyroclastic rocks, but more detailed study is required to support this interpretation. Two other possible methods of producing a fragmental ultramafic rock would be diatreme emplacement or tectonism. In other exposures the komatiites are massive to laminated and show possible spinifex texture in thin section.

In the northern portion of the east half of the map area a thick section of metawackes is intruded by a massive hornblende gabbro. Hornblende phenocrysts up to 1 cm long form about 15% to 20% of the rock and are set in fine-grained feldspar and amphibole. The rock has intruded the metasediments as sill-like bodies that conform to the general attitude of the host metawackes.

A distinctive quartz feldspar porphyritic stock intrudes the metasediments in the north central portion of the east half of the area mapped. The quartz phenocrysts are as large as 1 cm in diameter. The porphyry has been sheared and thus the matrix is composed mostly of sericite. The rock weathers chalk white and exhibits a mottled, apple green fresh surface. The porphyry can be traced over several miles across the central part of the township.

Archean felsic plutonic rocks form two large granitoid bodies within the map area. The southern one, the MacKenzie Granite, is a large intrusion consisting of medium- to coarse-grained, pink to slightly greenish granite composed primarily of microcline, oligoclase, quartz and biotite with accessory titanite, apatite, opaque minerals, and secondary sericite plus epidote (Rogers 1979). The intrusion is situated at the southern flank of the map area and occupies an area from Mount Baldy all the way to Birch Beach on Thunder Bay, a distance of approximately 22 km. The MacKenzie Granite has been faulted in the area 1.6 km northwest of Mary Harbour. Where not distorted by faulting, the granitic body is in the order of 3.2 km wide.

The northern body, the Penassen Lakes Stock, is very coarse grained, generally porphyritic and ranges in composition from granite to quartz monzonite with hornblende syenite and hornblendite phases. The syenitic and hornblendite phases appear to be restricted to the area of Highway 527 and westward. East of Highway 527, in the vicinity of the Penassen Lakes, the rock is a coarse-grained porphyritic quartz monzonite.

A satellite intrusion of similar hornblende syenite and a coarse porphyritic gabbro occur on the east flanks of the Penassen Lakes Stock. Feldspar crystals in the porphyritic gabbro are up to 13 cm long, comprise up to 80% of the rock, and define a near perfect mineral foliation.

The Proterozoic rocks of MacGregor Township consist of clastic and chemical sedimentary rocks of the Animikie Group. This group consists of two formations resting unconformably on the Archean basement, the Gunflint Formation (conglomerate, algal chert, chert carbonate, mudstone, limestone) and the Rove Formation. In the map area the Rove Formation (mudstone, wacke) is exposed in a narrow strip near Lake Superior. Isolated outcrops of a basal conglomerate occur throughout the southern portion of map area. In each case the Archean rocks beneath the conglomerate have been severely altered and weathered, possibly due to a period of pre-Gunflint weathering.

Diabase sills and dikes intrude all rock types in the area and are thought to be Middle Proterozoic in age.

STRUCTURAL GEOLOGY

The metavolcanic-metasedimentary sequence has a general easterly trend. Schistosity strikes parallel to the trend of the major units and has in many instances destroyed primary structures. The schistosity dips very steeply to vertically. Locally, the strike of the schistosity is undulating and may vary several tens of degrees in outcrop. Shearing has locally severely deformed the rocks, and in some cases mylonitic textures are evident. Near the contacts with granites primary features, such as pillows in volcanic rocks and graded bedding or crossbedding in sedimentary rocks, were obliterated.

Where facing directions are discernable in the Archean metasedimentary-metavolcanic sequence, they indicate a southerly facing sequence; locally some units face north, probably reflecting local folding.

Major regional faults transect the map area, trending northeasterly, north-northeasterly, and northwesterly. Some fault zones contain diabase dikes. Just southeast of Pass Lake Corners, at the far northeast corner of the map sheet, Gunflint Formation chert carbonate rocks have been brought into fault contact with Archean metasediments.

In most cases the Gunflint Formation is generally flat lying or dips southerly at shallow angles. In the area between Blende Lake and O'Connor Point on Lake Superior, the chert carbonate unit of the Gunflint Formation exhibits extraordinary brecciation and folding. This deformation appears to be restricted to the eastern portion of the map area.

ECONOMIC GEOLOGY

MacGregor Township is well known for silver occurrences. These almost always occur as veins associated with the Proterozoic/Archean unconformity (Tanton 1931; Franklin 1970). Usually these veins occupy fault or shear zones and contain sphalerite, galena, chalcopyrite, native silver, argentite, fluorite, calcite, amethyst, pale quartz, and barite. The vein systems appear to crosscut all lithologies and are best exposed along Highway 11-17 east of Thunder Bay. Veins mapped in 1984 and in 1985 vary in width from just a few centimetres wide to zones of several metres wide. They generally strike north, but are also found in some fault zones that strike northeasterly (Cornish Mine).

The amethyst-bearing veins are of the same relative age as the silver veins and occur throughout the map area. In most cases they crosscut the MacKenzie Granite and the Penassen Lakes Stock. A significant number of amethyst-bearing veins also crosscut felsic metavolcanics, as exposed on the hydro right of way approximately 2.4 km west of Mary Harbour.

Several old silver mines exist in the township. These are: Cornish Mine, 3A Mine, Beck Mine, Thunder Bay Silver Mine, Algoma Mine and 7Z location. While the economic viability of these silver bearing vein deposits today might be low, veins of this type have excellent potential for amethyst.

During the course of mapping, many quartz veins were sampled by the author and assayed by the Geoscience Laboratory, Ontario Geological Survey (OGS), for gold and silver. While not all samples yielded gold values, there is enough potential in some areas to warrant exploration for gold. For example, an area around an old quarry near the Nelson Road and Highway 11-17 junction may warrant exploration. Here sulphide-bearing veins, probably occupying shear zones in a siliceous, dark, metasedimentary rock, carry arsenopyrite, pyrite, zinc, and gold. Values of up to 1.06 ounces gold per ton were obtained from these veins in grab samples.

A zone of quartz stockwork and silicification of the surrounding rock exists north of the hydro line north of Birch Beach. No known exploration work has been done here and no old trenches were seen during mapping. Some of the larger quartz veins are up to 30 cm wide and exhibit pyrite gossans in places. One grab sample from the area returned values of trace gold and 0.76 ounce silver per ton (sampled by the author, assayed by the Geoscience Laboratory, OGS). The area has good potential for gold, and should be prospected.

Further east, about 2.4 km north-northwest of Mary Harbour and east and north of the Canadian Pacific Railway tracks, on a south-facing slope, there is a quartz stockwork that carries gold. A grab sample collected this season by the author and assayed by the Geoscience Laboratory, OGS, ran 0.02 ounce gold per ton. The individual quartz veins are narrow, but overall the zone itself is at least 2 m wide. The owner of the surface rights, Mr. A. Kurikka of Thunder Bay, states that there are several old pits and one shaft located between the Canadian Pacific Railway tracks and the hill. These were not seen during mapping. A 3 m wide quartz vein with a crack and seal texture is located on the north face of the above slope, near a small beaver pond. Further work is warranted.

Closer to the City of Thunder Bay, on the hydro line just north of Highway 11-17, about 2.5 km east of the junction of Highway 11-17 and Highway 527, two separate outcrops of quartz stockwork in felsic volcanic rocks deserve to be prospected. The zones are approximately 0.4 km apart. Analysis of a rock sample taken by the author from the hydro line at a point 0.4 km north-northwest of where the hydro line crosses Highway 11-17, yielded 185 ppb gold upon assay by the Geoscience Laboratories, Ontario Geological Survey, Toronto.

Komatiitic rocks located near Wildgoose Creek and the hydro line assayed up to 0.15% nickel.

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12. Hemlo Tectono-Stratigraphic Study

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INTRODUCTION

This season continued a multi-year mapping project designed to furnish a detailed geological map (1:10 000 published scale) and report on the geology of the area containing the Hemlo deposit. The Hemlo deposit is located about 35 km east of Marathon. The limits of mapping are Latitudes 48°40′30″N and 48°43′00″N, and Longitudes 85°51′30″W and 86°02′00″W and include parts of Bomby and Lecoeur Townships. As listed in Muir (1984), 26 properties lie wholly or partly within this 59 km² area.

The first third of the field season was spent doing a reconnaissance examination of structural features of major rock types along roads, railways, and lakes, from Heron Bay to Mobert, in order to gain an understanding of the regional structures and their relevance to the selected map area at Hemlo.

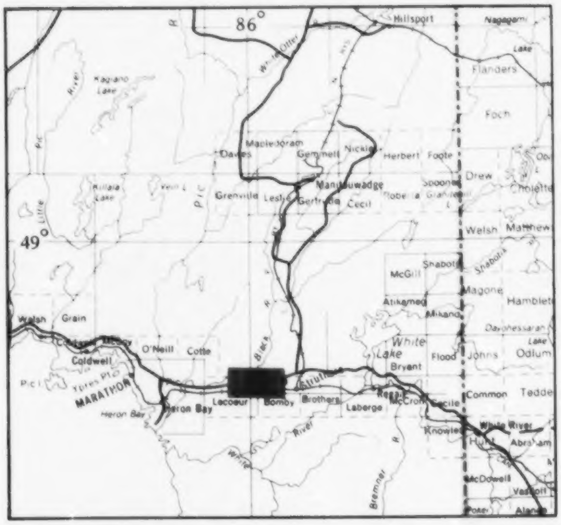
The remainder of the season was spent within the map area, particularly on the Lac Minerals Limited Williams Property Option, as key areas on this ground will soon be covered or blasted during impending construction and mining. Additional clearing of timber on this property from last year afforded some of the best exposure available in a crucial zone of structural complication, albeit if only for this field season.

GENERAL GEOLOGY

The general geology has been described previously by Muir (1982, 1984, 1985), Quartermain (1985), Valliant *et al.* (1985), and Brown *et al.* (1985) and will not be repeated here. Refinements to those descriptions by the Ontario Geological Survey and company geologists is, of course, ongoing.

Three main difficulties face the geologist at Hemlo: (1) recognition of primary sedimentary, volcanic, and structural features where they are still preserved; (2) recognition of secondary tectonic features; and (3) recognition of the presence and effects of hydrothermal alteration and/or regional metamorphism. Proper identification of these features, which is critical to understanding the geology and origin of the deposit and the surrounding rocks, will help to resolve such questions as: are the hangingwall pelitic metasediments adjacent to the barren sulphide zone and their metamorphic mineral assemblages representative of a primary composition or of a hydrothermal alteration?; are certain units sufficiently sheared/mylonitized to preclude identification of their protolith?; are apparent "clasts" of primary (clastic sedimentary or pyroclastic) or tectonic origin?; is the mineralized zone affected by the large, incompletely defined fold structure north of the ore horizon?; have structural features (i.e. lineations, configuration of minor structures, etc.) been correctly interpreted in this highly and complexly deformed area?

Although the degree of deformation is strong and locally intense, the major protoliths were: sedimentary rocks derived from erosion of consolidated and unconsolidated volcanic rocks, and material of undetermined origin; and pyroclastic/subvolcanic rocks. Hence, it is to be expected that clasts were initially present in various units and that such clasts would also have been deformed by processes which include boudinage, shear, and transposition.


86°
49°
Hillsport
Nagagami Lake
Flanders
Foch
Kagiano Lake
Maplejoram
Davies
Gemmell
Nickle
Herbert
Foote
Manitouwadge
Grenville
Leslie
Gertrude
Cecil
Drew
Welsh
Matthew
McGill
Shabotik
Magone
Hamblet
Atikameg
Mikano
White Lake
Bryant
Flood
Johns
Odlum
Walsh
Grain
O'Neill
Cotte
Coldwell
MARATHON
Heron Bay
Lecoeur
Bomby
Brothers
Laberge
McCron
Cecile
Common
Knowles
White River
Abraham
McDowell
Bremner
Pic R.
Black R.
White R.

LOCATION MAP

Scale: 1:1 584 000
or 1 inch to 25 miles

Before mapping of the main Lac Minerals Limited Williams Property Option, the rocks to the south of Highway 17 down to Molson Lake, where a tailings dam is under construction, were briefly examined. The rocks south of the highway are grey, biotite-feldspar lithwackes and siltstones deposited as turbidites, similar to those seen in the footwall and hangingwall of the deposit, and thickly to crudely bedded, fine grained, amphibole-bearing rocks, likely of volcanic origin. Farther south are mafic rocks with compositional layering (i.e. gneissosity) that may originally have been bedding, and amphibolites that are likely metamorphosed flows. At the dam site, which lies about 100 m northeast of the contact with the Pukaskwa Gneissic Complex, there are amphibolites and amphibolitic metasediments which have been intruded by medium to coarse grained metapyroxenites consisting largely of hornblende and actinolite, and by a swarm of granitoid dikes of intermediate to felsic compositions and of multiple ages. The metapyroxenites are similar to those found in the same host rocks, the Playter Harbour Group, to the west (Muir 1982).

Considerable time was spent in the newly cleared out area north of the Lac Minerals Limited main shaft (Williams Property Option), and at the "Heritage" outcrops northwest of the main shaft. It is in the cleared area that a major fold was previously strongly suspected (Valliant *et al.* 1985) and this season was confirmed to be present (*see* section on Structural Geology). All units dip to the north at about 60° to 70°.

The footwall rocks of the mineralized zone, as exposed on surface northwest of the main shaft, are 'felsic' (present composition), and consist largely of sericite, quartz eyes, and feldspar, and are possibly of volcanic or subvolcanic origin. They locally display fragments and have undergone shear folding.

Two 'gossans' mark the upper and lower limits of the mineralized zone (or ore zone depending on the grade), and are separated by a virtually non-rusty zone. The lower gossan appears to consist largely of rusty, sericitic and/or feldspathized (and locally silicified?) metasediments which show good evidence of tight folding and dextral shearing. Some of the metasediments are interpreted by the author to be granule and pebble conglomerates, consisting largely of volcanic detritus. The central zone consists of metasediments which exhibit considerable deformation and feldspathic/biotitic alteration. The upper gossan appears to consist of feldspathized metasediments. Both gossans contain rocks which locally have developed small, white, retrograded porphyroblasts, possibly of plagioclase.

The following listing gives a general summary of the main lithological units ('thicknesses' are measured horizontally), from southwest to northeast that stratigraphically overlie the mineralized zone in this vicinity:

20 m - tightly folded, mixed feldspathic lithwackes, siltstones, calc-silicate units, and volcaniclastic granule and pebble conglomerates, some of which show grading;

50 m - medium to dark grey wackes and siltstones deposited as turbidites;

200 m - relatively coarse, thickly bedded volcaniclastic wackes consisting largely of intermediate to felsic, plagioclase and quartz-plagioclase phyric clasts up to 2 cm long, and crystals. These wackes are interbedded with white to light-grey-weathering, thinly laminated to thinly bedded, feldspathic siltstones. Both the wackes and siltstones are likely turbidite deposits. Dark green calc-silicate beds consisting of amphibole and carbonate (?) increase in abundance to the north.

60 m - garnet and/or staurolite-bearing, medium to thinly bedded pelitic sediments with interbedded calc-silicates;

major fold axis-(*see* section on Structural Geology). The fold closes to the northwest;

90 m - same pelitic sedimentary sequence as above. Within the pelitic sediments is a single, distinctive unit of equivocal origin which was traced around the fold hinge and for at least 600 m on the limbs. The unit is tentatively interpreted as a primary intra-formational breccia, possibly resulting from slumping;

20 m - thickly bedded, light grey feldspathic lithwackes and siltstones with calc-silicate beds;

300 m - relatively monotonous packages of turbidites consisting of medium to dark grey biotite-feldspar lithwackes and siltstones without calc-silicate beds. Rarely, rounded quartz crystals about 1 mm in diameter were found in the feldspathic siltstone.

The important point, is that the overall stratigraphic succession does not appear, for the most part, to be repeated across the fold axis; a configuration that could be accounted for in several ways (*see* section on Structural Geology).

Primary sedimentary features observed, in addition to bedding and presence of clasts, include grading of feldspar crystals and clasts, compositional grading reflected in the presence of amphibole (empirically antithetical to a decrease in feldspar grain size), and rip-up clasts. Top determinations indicate there are a number of facing reversals and that the major fold mentioned above is a reclined overturned syncline.

Amphibolitic dikes and dikelets locally intruded the metasediments. Strike-conformable dikelets are difficult to distinguish from calc-silicate beds of similar thickness except that the latter are commonly garnet bearing and generally have undergone a different structural history. At one well-exposed location two such dikes each about 20 cm thick were noted. One was strike-conformable, had undergone boudinage with limited separation of boudins, and had medium to coarse grained quartz-tourmaline infillings; local feldspathic alteration with tourmaline mineralization occurred in the wall rocks. The other was disconformable, had undergone a greater degree of boudinage with accompanying apparent rotation of boudins, and had quartz infillings; no tourmaline was observed.

STRUCTURAL GEOLOGY

The style of deformation in the map area varies considerably from place to place which partly reflects the mechanical characteristics of the parent lithologies and partly the diversity of local deformation processes and events. The former is controlled largely by inherent competencies, and the latter by relationships to fold hinge zones and shear zones. Descriptions of structural features within parts of the map area have previously been given by Hugon (1984), Muir (1984), and Valliant *et al.* (1985).

Three relatively major folds were examined this season: (1) a reclined synformal fold 1.4 km north of Highway 17 on Highway 614; (2) a reclined, overturned syncline 150 m west of Cedar Creek on Highway 17; and (3) a reclined overturned syncline about 200 m north-northeast of Moose Lake (*see* the large fold structure mentioned in section on General Geology). Axial planes and fold hinges of these folds, constructed from bedding cleavage measurements, show that, from east to west: (a) the axial planes become steeper; and (b) the fold hinges change from east-northeast trending/shallow plunge, through northeast-trending/moderate plunge to north-northwest trending/moderate plunge about an axis oriented at 010° and on a small circle dipping 60° from north. More data are needed to confirm and explain this trend but one possibility is that previous folds have been refolded about axes that trend 190° and plunge 40°.

Crenulation cleavages can be locally found throughout much of the map area and in many cases form the third fabric (S_3) in the rocks. One example, outside the main area of study this season, was at the Lac Minerals Limited dam site at Molson Lake. Here, bedding in mafic sediments with a conformable west-southwest trending fabric (S_1) was deformed about minor, steeply east-plunging 'Z'-shaped folds with accompanying southwest-trending axial planar cleavage (S_2), which was later crenulated about an east-trending fabric (S_3).

The following structural features were observed on the northern part of the Lac Minerals Limited Williams Property Option:

- an early, weakly to moderately well-developed foliation (S_1), parallel to bedding (S_0), which in most cases is not discernible and is thought to have been mainly obliterated;
- an intermediate northwest to west-northwest trending pressure solution cleavage (S_2) representing the axial planar cleavage of the large fold structure. This cleavage: ranges from poorly to well developed; is best developed in metasiltstones; is locally refracted and/or curved; and locally produces a striped appearance (stripes up to 1 cm wide) noticeably oblique to bedding;
- a later northeast to east-northeast trending, locally penetrative foliation (S_3) which locally causes a crenulation of the S_1 fabric and which appears to be associated with similar-trending low angle (to bedding) dextral faulting/shearing during ductile and brittle stages. This fabric may be related to the dextral shear fabric which is well developed within the ore zone. Mineral lineations are fairly consistently west-northwest trending and plunge at about 40° to 50°.

Very tight isoclinal folding accompanied or followed by dextral shearing has resulted in boudinage, dislocation of fold limbs, and minor to strongly developed transposition of bedding. Metasediments with folded to boudinaged calc-silicate beds have been intruded by amphibolitic dikes and dikelets which are slightly deformed and appear to be affected only by the S_3 associated structures. Some feldspar porphyries have intruded rocks that had already acquired a well-developed S_2 fabric. In many cases, rip-up clasts are not notably affected by the S_2cleavage, that is they are not realigned parallel to that fabric.

Transposition of bedding also occurs away from the fold hinge in zones parallel to bedding. These zones range from poorly to well defined depending on the lithology involved; within them bedding is highly disrupted and discontinuous. In a specific case, a 2 m thick, east-trending zone of highly transposed, thinly bedded siltstones and calc-silicates is bounded to the north and south by well-defined straight bedding which is locally transected slightly by the boundaries of the zone. This zone can be traced along strike for 10 m where it terminates abruptly in a highly discordant folded contact. On the other side of this contact lies non-transposed, thickly bedded, feldspathic lithwackes containing rip-up clasts and a moderately well-developed S_3 cleavage along which feldspar, quartz, and amphibole have migrated.

Bedding plane breccias are common in the more feldspathic lithwackes. These breccias formed during a late brittle stage of deformation as they have not been ductilely deformed. They occur in both unsheared and mylonitized hangingwall and footwall rocks as thick (up to 0.5 m) to thin (hairline) zones subparallel to bedding. One side of the breccia zone commonly lies consistently along one bed for distances of over several metres, whereas the other side cuts erratically up or down section creating highly variable thicknesses along strike. Fragments range from fine to coarse and are generally angular. Matrixes consist of crushed material and appear in some breccias to be feldspathic; staining of these rocks commonly indicates some addition of potassium in the matrix. Where breccia thicknesses are less than several millimetres, the material is commonly pseudotachylite. The breccias denote strike-slip displacements of unknown magnitude on numerous fault planes. These breccias have not been observed either in the dirty siltstones and pelitic sediments, or in the mineralized zone, which is likely a function of relative competency.

The above examples of local structural complexities illustrate why simple interpretations of lithological configurations are not possible in this area. In addition, many of these complexities likely involve the ore zone and hence its history and configuration may be complex and difficult to relate to the overall picture given the restricted observational environment of an individual mine.

CONCLUSIONS

If the major structures mentioned above have been properly identified then there is a strong possibility that some or all of the stratigraphy within and adjacent to the mineralized zone is overturned (compare with Figure 5 *in* Patterson 1984). This would make some previous assumptions about the stratigraphy of the Hemlo deposit, previously considered to be up-right facing, invalid.

It is much too early to accept any model for the origin of the Hemlo deposit. It is clear that the geology (lithologically, structurally, metamorphically) is much more complex than previously considered, that some of the early observations and interpretations can now be rejected or relegated to serious reconsideration, and that the deposit cannot be proven to be syngenetic at this stage because too many of the above factors were not fully considered and have not been resolved.

Interpretations of origin based on isotopic data (*see* Hattori and Cameron 1984) and analogies drawn to modern analogues involving sinter deposits (*see* Quartermain 1985; Goldie 1985) are at best speculative and could tend to give an erroneous impression of the geological setting of the Hemlo deposit. After several years mapping of the regional and local geology of the area the author's view is that the barite units at Hemlo have not been shown to be stratiform and that there is no evidence of siliceous sinter deposits involved in the Hemlo deposit.

Conversely, the recognition of structural and metamorphic features (including hydrothermal alteration), be they related to mylonitization, transposition, or feldspathization, does not in itself disprove a syngenetic origin for the mineralization. The timing of all these events, particularly that of mineralization, is crucial to proof of origin and will be determined only after much diligent recording of data over the coming years on a local setting scale and mine scale.

ACKNOWLEDGMENTS

The author would like to thank the following, listed alphabetically, for their cooperation and fruitful discussions during the field season: Peter Cooper (Noranda Exploration Limited), Gillian Hand (Ontario Geological Survey), Pat Kennedy (Noranda Incorporated), Howard Poulsen (Geological Survey of Canada), Kevin Thompson (Lakehead University), Phil Walford (Lac Minerals Limited), and Bob Weicker (Lac Minerals Limited).

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13. White Lake Area, District of Thunder Bay

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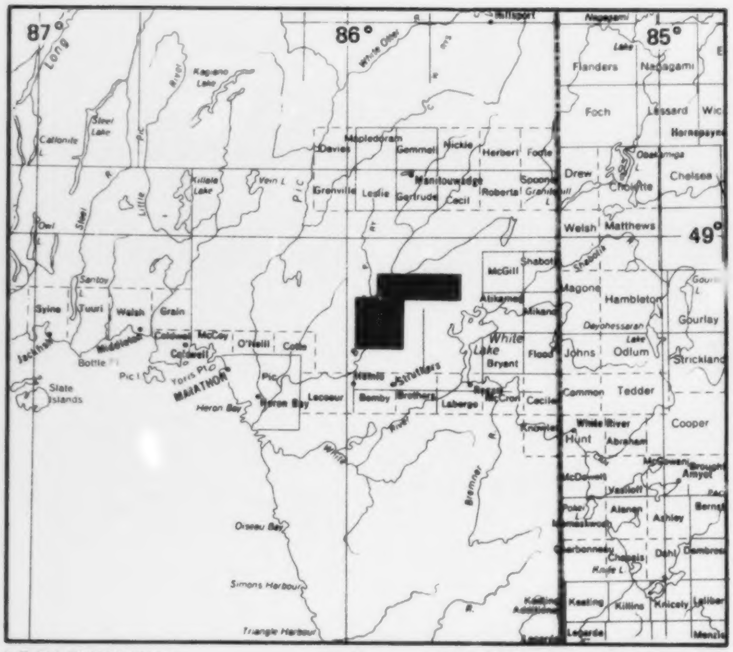
INTRODUCTION

During the summer of 1985 two separate areas, referred to, respectively, as the Northern and Western Areas of the "Hemlo Belt" were mapped at the scale of 1:15 840. The Northern Area is bounded by Latitudes 48°52'30"N and 48°54'54"N, and Longitudes 85°38'30"W and 85°57'00"W, and adjoins the Theresa Lake Section of the White Lake Area (Siragusa 1985) to the north. The Western Area is bounded by Latitudes 48°45'33"N and 48°52'30"N, and Longitudes 85°50'00"W and 85°57'33"W, and adjoins the Theresa Lake Section of the White Lake Area (Siragusa 1985) to the west. Both the Northern and Western Areas were previously mapped by Milne (1968) in lesser detail.

Access to the central part of the Northern Area is by the 8 km long Dead Otter Lake bush road, which connects with Highway 614 (the Manitouwadge Highway), and thence by a 4.5 km long waterway which includes Dead Otter Lake and Dottec Lake. Eastern parts of the Northern Area can be reached by a 20.5 km long waterway that connects the northern tip of Ravine Lake to Highway 17 via the Spruce Bay area and the Narrows of White Lake. Alternatively, an elongated northeast-trending lake, locally known as Roger Lake, can be utilized to reach eastern parts of the Northern Area by bush plane; aviation service is available in Manitouwadge. Highway 614 gives access to the western part of the Northern Area, but its usefulness as a base line for bush traverses is limited because the highway crosses the northeast-trending ridges of supracrustal rocks underlying the area, rather than being parallel to them. A natural base line for traversing these ridges is the southern segment of Mobert Creek, an eastern tributary of the Black River, which has a general northeasterly trend and is approximately 5 km long. In the early summer of 1985, only a few log jams and minor rapids were found along this segment of Mobert Creek which proved to offer practical canoe access.

Highway 614 parallels the eastern margin of the Western Area, but is generally too far east to be utilized as base line for mapping of outcrop areas in the central and southern parts of it. Hence, the Black River had to be utilized for this purpose. The Black River can be reached by a bush road which is about 7 km long and connects with Highway 614, 1.5 km south of Summers Lake. Access to the river via this road is, however, of limited practical use as the road reaches the river upstream of the first of five sets of rapids found along the segment of the river within the Western Area. A relatively flat natural clearing covered by gravel and small boulders occurs on the eastern bank of the Black River, at the very head of the second set of rapids. This clearing is the only one in the area large enough to allow access to the river by helicopter, and was thus utilized in the late summer of 1985. Helicopter service is available at the Marathon airport.


87°
86°
85°
49°
Hillsport
Nagagami
Flanders
Foch
Lessard
Chelsea
Caramat
Kagiano Lake
Steel Lake
Cationite
Killala Lake
Vein L.
Pic
Little
Steel
Black
White Otter
Davies
Mapledoram
Gemmell
Nickle
Herbert
Foote
Grenville
Leslie
Manitouwadge
Gertrude
Cecil
Roberta
Drew
Welsh
Matthews
McGill
Shabotik
Magone
Hambleton
Gourlay
Santoy
Syine
Tuuri
Walsh
Grain
Jackfish
Middleton
Coldwell
McCoy
O'Neill
Cotte
Bottle Pt.
Pic I.
Slate Islands
Tony's Pt.
MARATHON
Heron Bay
Lecours
Hemlo
Bomby
Brothers
Laberge
White Lake
Bryant
Flood
Johns
Odlum
Strickland
Common
Tedder
Cecile
Kramer
White River
Hunt
Abraham
Cooper
McDowell
Vasiloff
Ashley
Bernst
Dahl
Dembrowski
Chabanel
Keating
Killins
Knicely
Laliberte
Lagarde
Menzies
Oiseau Bay
Simons Harbour
Triangle Harbour
Bremner

LOCATION MAP Scale : 1 : 1 548 000 or 1 inch to 25 miles

MINERAL EXPLORATION

Old and recent claim and/or grid lines were noted throughout the Northern and Western Areas. During the summer of 1985, geophysical surveys and prospecting were carried out by Key Lake Explorations Limited on a property held by this company in the Summers Lake area (E. Dillman, President, Key Lake Explorations Limited, Toronto, personal communication, 1985). Noranda Exploration Company Limited carried out backhoe trenching of three geochemically and geophysically anomalous zones in the Prime North property, and further trenching and sampling were subsequently completed in the area. No significant sulphide concentrations were found, and all the trenches assayed returned only traces of gold (J. Gibson, Manager of Evaluation, Noranda Exploration Company Limited, Toronto, personal communication, 1985).

GENERAL GEOLOGY

One of the two objectives of the 1985 field work was the mapping of the supracrustal rocks underlying the Northern and the Western Areas in greater detail than the previous survey (Milne 1968), and the other was the continuing study of the gold distribution in the gossans hosted by these rocks. To meet these objectives, no significant mapping was carried out in the regional granitic rocks. The supracrustal rocks were mapped in the greatest detail possible at the scale of the present survey, and many rock samples were collected for gold assays.

The Northern Area is underlain by a mafic metavolcanic belt which has a general east-northeast trend and attains a maximum width of about 4 km in the western part of the area. Structural evidence as well as outcrop pattern seem to leave little doubt that this width is largely attributable to a major northeast-trending fold which Milne (1968) named the Dotted Lake Syncline. In the eastern part of the Northern Area, the belt narrows and eventually pinches off approximately 18 km east of the point of maximum width. Metamorphism of the volcanic rocks has resulted in well developed foliation throughout the length of the belt, small shear zones and parasitic folds of local occurrence, and migmatization particularly at the eastern margin of the belt. Lithologically, however, the belt consists of metavolcanics of essentially uniform basaltic composition. Although recognizable pillows are locally present, these structures are generally too deformed to be useful for top determinations. Elongated northeast-trending units of hornblende gabbro and serpentinized peridotite locally intrude the metavolcanics at the southern margin of the belt. The peridotitic unit is longer than indicated by previous mapping (Milne 1968). The mafic metavolcanics underlying the southwestern corner of the Northern Area are truncated by a major fault which has a dominantly southern trend and was named by Milne (1968) the Jenny Creek Fault.

The Western Area is diagonally crossed by a northeast-trending belt consisting dominantly of metasediments with subordinate intermediate and mafic metavolcanics. To the northeast, this belt narrows and eventually abuts against the Jenny Creek Fault where it attains its minimum width of 1.6 km. In addition to the Jenny Creek Fault, however, other faults occur at the "junction" of this belt with the mafic metavolcanics underlying the Northern Area. One such fault, which was named by Milne (1968) the Pinegrove Lake Fault, has a northwesterly trend, and could have some economic significance (*see* "Economic Geology"). To the southwest, the belt extends beyond the present map area within which it attains an estimated maximum width of 3.5 km. The lithologically outstanding feature of this belt is the presence of a large unit of polymictic conglomerate consisting of dominantly granitoid clasts, commonly a few centimetres to about half a metre in size, embedded in a mafic-poor matrix of quartzofeldspathic arenite of grey to tan colour. Easily accessible outcrops of this unit occur along the Black River bush road (*see* "Introduction"), approximately 1300 m west of the Canadian Pacific Railway line. The conglomerate found at this locality has a relatively uniform medium to fine grained matrix which locally shows well preserved bedding. Prominent conglomeratic outcrops occur also at, and east of the fifth set of rapids on the Black River, 7 km southwest and along strike of the exposures mentioned above. The conglomerate underlying this area is characterized by somewhat larger individual clasts, and by a generally chaotic fabric and gritty texture of the matrix.

The intermediate metavolcanics include plagioclase porphyritic flows that locally show well developed pillows, as well as pyroclastic units consisting of ash-size to block-size lenticular felsic clasts within a matrix which is commonly andesitic in composition, and aphanitic or porphyritic in texture. Two or more of these types can be closely interlayered with each other, or with mafic metavolcanics and metasediments, within cross-strike widths of 20 to 30 m (eg. outcrops along Highway 614 immediately north of the prominent diabase outcrop opposite Summers Lake). Such occurrences point to a regime of relatively rapid changes in the conditions of volcanism and intervening sedimentary processes, and this appears to be a characteristic feature of the northeast-trending belt underlying the Western Area.

ECONOMIC GEOLOGY

During present mapping, 327 rock samples were collected from about 80 gossans hosted by the supracrustal rocks underlying the Northern and Western Areas. These samples were shipped to the Geoscience Laboratories, Ontario Geological Survey, Toronto, where they are presently being assayed for gold (in ppb) and, in a few cases, for base metals. Upon completion of this work the results of the assays will be published following the same format adopted in the Preliminary Map of the Theresa Lake Section of the White Lake Area (Siragusa 1985). The sampled gossans vary in colour from light yellowish or pink hues, to dense orange, red, or brown and the exposed area of individual gossans ranged from half a square metre or less, to many square metres. As no assay data are available at the time of writing the gold potential, if any, of the sampled gossans is presently unknown. General observations relevant to these gossans can be summarized as follows:

1. In the Northern Area, gossans are both less frequent and individually less extensive than they are in the Western Area.
2. In a few gossans found in the Western Area, massive pyritic laminae or thin beds occur in fine to medium bedded metasediments, or interbedded metasediments and metavolcanics. While this mode of occurrence of pyrite points to its probable syngenetic origin, for most other gossans in the Western Area there seems to be little doubt that sulphide mineralization (mostly pyrite) was a structurally controlled process. In fact, in the majority of cases the pyrite fabric coincides with metamorphic foliation and, furthermore, many gossans are clustered adjacent to major faults such as the Jenny Creek Fault and, to a lesser extent, the Pinegrove Lake Fault. Massive fine grained sphalerite stringers a few millimetres thick, and some lenticular blebs of fine grained galena up to 2 cm in size, were noted in one such gossan which is found in silicified and pyritized intermediate metavolcanics adjacent to the Pinegrove Lake Fault.
3. A characteristic feature common to the gossans adjacent to the Jenny Creek and the Pinegrove Lake Faults is that metamorphic foliation, and hence the planar fabric of sulphide mineralization, intersects the fault plane either normally (Pinegrove Lake Fault), or at about 45° (Jenny Creek Fault). This feature is probably a negative element when considering lateral continuity as, on the basis of the field data presently available, gossans do not seem to be traceable across the faults.
4. The structural relationships mentioned above (item 3) apply to the area where the northeast-trending belt abuts against the Jenny Creek Fault (*see* "General Geology"). Conversely, the gossans found southwest of this area are characterized by a remarkable lateral continuity. In fact, they occur essentially within a relatively narrow northeast-trending zone located within the western margin of the belt and parallel to the granitic contact. This zone has a maximum width of about 300 m and a length of at least 5.8 km. Laminar pyritic disseminations along the (northeast-trending) plane of foliation or shearing are ubiquitous throughout this zone which seems to transgress different lithologic types, and is locally characterized by conspicuous development of muscovite.

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S14. Mishibishu Lake Area, Districts of Algoma and Thunder Bay

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This project was funded by the Ministry of Natural Resources under the Special Projects to Assist Resource Communities (SPARC) Program.

INTRODUCTION

The area encompassed by this project lies some 35 km west of Wawa. The eastern 10% is within the District of Algoma while the western 90% is within the District of Thunder Bay. Parts of the surveyed townships of Legarde, St. Germain, and Groseilliers were mapped while the balance of the project area was in unsurveyed territory. The approximate boundaries are Latitudes 47°55'00"N and 48°07'30"N, and Longitudes 85°15'00"W and 85°44'00"W covering some 830 km^2 (Location Map).

The survey consisted of helicopter-assisted detailed mapping of the metavolcanic-metasedimentary belt at a scale of 1:15 840 and reconnaissance mapping of plutonic areas at the same scale. A total of 16 people were directly involved in this project.

Information on mineral occurrences was gathered from Assessment Files, Ontario Ministry of Northern Affairs and Mines, Sault Ste. Marie, and the Assessment Files Research Office (AFRO), Ontario Geological Survey, Toronto.

The earliest recorded work in the map area was that of Agassiz *et al.* (1850) and Logan (1863). It consisted of reconnaissance trips through the general Lake Superior area. Coleman (1899) and Coleman and Willmott (1899) outlined the 'greenstone' belts and described the iron 'formations'. Bell (1905) covered part of the present map area as part of a larger survey and Evans (1942) mapped the area between Mishibishu Lake and the East Pukaskwa River. The Kabenung Lake belt north of the map area was mapped in detail by Goodwin (1954).

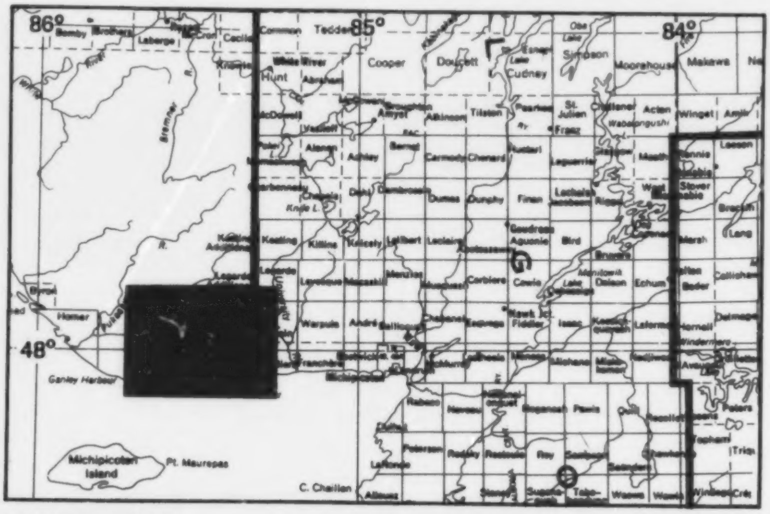
As a preliminary to this detailed survey, Bennett and Thurston (1977) performed a helicopter-supported reconnaissance mapping survey in 1968. In conjunction with this survey a regional geochemical reconnaissance was made by Wolfe (1976).

The area was surveyed by airborne magnetometer as part of a joint Ontario Department of Mines-Geological Survey of Canada effort in 1963 (ODM-GSC 1963a, 1963b. 1963c, 1963d, 1963e, 1963f) and parts were covered by an input survey done for the Ontario Geological Survey in 1980 (OGS 1980a, 1980b).

MINERAL EXPLORATION

The metavolcanic-metasedimentary belt had been staked solid before the project began. The most active area for exploration is immediately north of Mishibishu and Mishi Lakes. Gold was the major, in fact, the only commodity being sought after.

The main companies exploring the belt are Westfield Minerals Limited and Muscocho Explorations Limited. Westfield Minerals Limited has just recently completed a diamond drill program of 8000 feet. Muscocho Explorations Limited has completed a first phase of 8000 feet of diamond drilling and as of 31 August 1985 is nearing the end of a second phase of 8000 feet. Durham Resources Incorporated had a field party doing mapping and sampling on their ground during the field season. Prospecting Geophysics Limited also had crews in the area doing work for various concerns, most notably MacMillan Energy Corporation who recently optioned their ground to Granges Exploration Limited. Other interests in the area are Conscot Resources Limited, New Beginnings


86°
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84°
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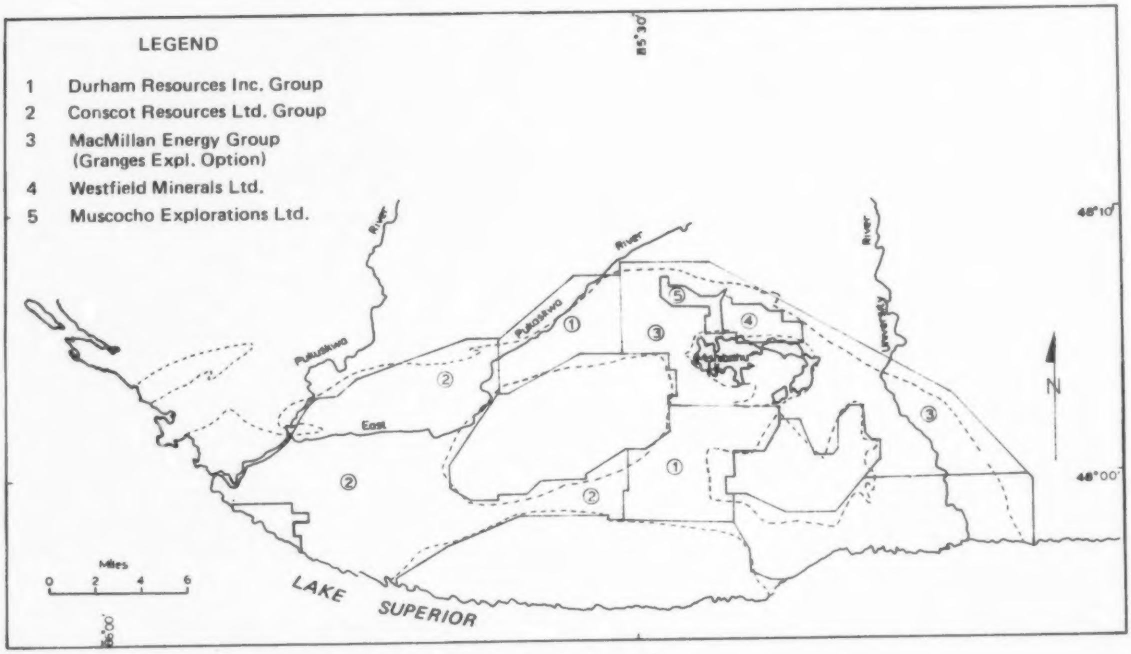
Bomby
Brothers
Laberge
Cecile
Common
Tedder
Cooper
Doucett
Cudney
Simpson
Moorehouse
Makawa
White River
Hunt
McDowell
Amyot
Atkinson
Tilston
St. Julien
Franz
Acton
Wabatongushi
Winget
Ashley
Bernat
Carmody
Chenard
Lepuerrier
Lesson
Stover
Dambrosio
Dumas
Dunphy
Finan
Lochalsh
Knife L.
Keating
Killins
Kelcely
Lalibert
Leclaire
Goudreau
Aguonie
Bird
Marsh
Lang
Legarde
Menzies
Corbiere
Cowie
Dolson
Echum
Bader
Callinan
Warpula
Andre
Hawk Jct.
Fiddler
Isaac
Laforme
Hornell
Windermere
Delmage
Homer
Ganley Harbour
Michipicoten Island
Pt. Maurepas
C. Chaillon
Rabazo
Peterson
LaRonde
Allouez
Rennie
Peters
Topham
Roy
Wawa
Wicksteed

LOCATION MAP

Scale : 1:1 548 000 or 1 inch to 25 miles.


LEGEND
1 Durham Resources Inc. Group
2 Conscot Resources Ltd. Group
3 MacMillan Energy Group (Granges Expl. Option)
4 Westfield Minerals Ltd.
5 Muscocho Explorations Ltd.
85°30'
48°10'
48°00'
86°00'
River
River
Pukaskwa
Pukaskwa
River
East
University
Mishibishu Lk
①
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③
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N
Miles
0
2
4
6
LAKE
SUPERIOR

Figure 1. Properties in the Mishibishu Lake area. (Project S14.)

Resources Incorporated, Villeneuve Resources Limited, Brass Ring Resources Incorporated, and Tundra Gold Mines Limited, all of which are controlled by the same principals. Figure 1 shows the location of the major claim blocks and the ownership of them. Most of the work in the map area, aside from diamond drilling, has consisted of an airborne magnetometer and electromagnetic survey of the belt by Aerodat for Prospecting Geophysics Limited. This survey is for sale to groups holding ground in the area. Individual companies have done geological mapping, soil geochemical surveys, and various types of ground geophysical surveys. Some surveys have been submitted for assessment credit while others have not. Westfield Minerals Limited has done considerable manual stripping of its main showings and some minor manual and light machine work has been done on the Muscocho Explorations Limited ground. Due to the lack of a road into the area, no large equipment has been brought in to do extensive power stripping. This type of work would be an invaluable asset in mapping this structurally complex area.

More details of exploration programs will be provided by Heather (this volume).

Noranda Exploration Company Limited and Asarco Exploration Company of Canada Limited conducted base metal exploration around Katzenbach Lake and along Macassa Creek in the past. Some early iron ore exploration was done around David Lakes and on other iron-rich units in the map area.

GENERAL GEOLOGY

Geologic mapping at a scale of 1:15 840 began on Mishibishu Lake in the main areas covered by exploration activity and was thereafter extended into the other parts of the belt.

In and around the Mishibishu Lake area there appears to be a series of (iron tholeiitic?) basalt flows and pyroclastics (tuffs). These flows are massive with some extensive pillowed basalt flows being observed. Porphyritic flows often with plagioclase phenocrysts 1 to 2 cm and up to in excess of 10 cm were used as marker units especially in the area immediately north of Mishibishu Lake. The basaltic flows and pyroclastic units often are separated by interflow metasediments. These flows are commonly separated by felsic welded tuffs and porphyritic flows. In some cases, however, the felsic units show definite crosscutting relationships to the mafic units indicating they are intrusions.

Contacts between the mafic and felsic units are rarely observed, however, and further petrographic and lithogeochemical work will have to be done on most units to establish these relationships. Preliminary thin section examination has established a tuffaceous origin for two of the felsic units.

Initial observations suggest that the rocks near Mishibishu Lake are proximal to a volcanic centre. Felsic and intermediate metavolcanics comprise <10% of the rocks in the area central to Mishibishu Lake with mafic metavolcanics and metasediments comprising 30% to 40% each and the remaining 10% to 30% made up of plutonic rocks.

Some hiatus in volcanism likely occurred during which time extensive uplift and erosion occurred.

This is evidenced by large deposits of conglomerate, greywacke, and turbidite sequences. Petrochemical studies are proposed to establish whether more than one cycle of volcanism is represented, each separated by an erosional cycle.

The geology of the western part of the project area toward the Pukaskwa River is characterized by a more varied metavolcanic sequence. Considerable felsic and intermediate flows and pyroclastics separate and are intercalated with the mafic metavolcanic and metasedimentary units, suggesting a more distal phase of volcanism or possibly a distinct volcanic centre of a more felsic nature.

Clastic metasediments are extensive and could be traced from the eastern boundary through to the western boundary of the project area. Some metasedimentary beds were easily traced for several kilometres while others were less distinct or interdigitated with other units. The polymictic clast-supported conglomerate beds are the most distinctive and easily traced units. Clast counts and further petrographic work is scheduled to attempt to establish the origin of the clasts in the conglomerate and whether they are locally derived or from a more distant source.

Chemical metasediments are almost exclusively 'exhalative' magnetitic chert interbedded with magnetite-bearing iron-rich rocks. These oxide affinity iron-rich units are best described as 'lean' in that the author estimates soluble iron content to be <20%. One thin (10 to 20 cm) sulphide affinity iron-rich unit was noted on the Muscocho Explorations Limited property just east of Macassa Creek and west of Magnacon Lake. To date no significant gold values have been reported from any chemical metasedimentary units.

Some coarse grained mafic units were mapped in all parts of the map area, and whether they are gabbros and thus plutonic in origin or merely sills and minor dikes related to mafic volcanism or thick mafic flows is not clearly evident at this writing. Further lithogeochemical studies are planned in an attempt to resolve this issue.

Several felsic to intermediate plutonic bodies were delineated. The most extensive is the Mishibishu Lake monzonite stock. This rock is coarse grained, orange-red to orange with magnetite dustings throughout and extensive epidote alteration. Quartz is rare and pyroxene is the major mafic mineral. Sodium cobaltinitrite staining for potassium feldspars has demonstrated that the plutonic rocks are at least one order of magnitude more sodic than previous mapping indicated. Further lithogeochemistry and petrography is planned to better classify these rocks.

Some of the plutonic bodies are massive while others are foliated which may indicate age differences. For example, Turek *et al.* (1984) have found relatively young-looking batholithic rocks with older ages than older-looking foliated batholithic rocks. Four samples were gathered for U-Pb age dating this winter at the University of Windsor: one sample from the Mishibishu Lake Stock, one from a welded tuff south of Mishibishu Lake, and one each from felsic flows or sills west of Mishibishu Lake along Macassa Creek and west of the Pukaskwa River, respectively.

The whole map area is extensively cut by diabase dikes. Very few crosscutting contacts between dikes were observed, but where such observations were made a case can be made for the oldest having intruded in a northerly direction while the younger set trends northwesterly. The older the dike the more mafic its appearance is another general observation.

Regional metamorphism is greenschist facies rank with amphibolite facies rank reached near the contact with stocks and batholiths.

Pleistocene deposits are in general confined to clays and till that mantle the area from zero to several tens of metres thickness. Only a few eskers and very little outwash were observed.

Most companies have had a fair degree of success delineating favourable prospecting areas by soil geochemistry. Once a consistent pattern of above-background gold values (1000 ppb and up) is evident, stripping and trenching follow. Should surface and trench sampling produce encouraging results an attempt is made to follow the zone along strike and establish some depth to it by diamond drilling. With the exception of Westfield Minerals Limited Discovery 'showing', all gold showings seem to be hosted in metasediments; the Discovery 'showing' of Westfield Minerals Limited being in mafic metavolcanics.

A simplified picture of the mineralized areas would appear at this time to have the following characteristics: extensive structural deformation characterized by shearing, kink bands and dilation zones filled with quartz; and an alteration pattern around the quartz stockworks characterized by a chloritic outer halo, an ankeritic inner halo, and a sericitic inner core. All the mineralized areas are characterized by the presence of quartz veins in the host rocks. Major host rocks are wackes, conglomerates, argillites, and oligomictic quartz granule conglomerate. Until extensive stripping is done classification of the deformed rocks is quite difficult and even clean outcrops make the task only slightly less difficult.

Airborne magnetic and electromagnetic methods have been of some assistance in outlining the felsic plutonic rocks. The extensive diabase dike system causes considerable 'noise' further complicating interpretation of the geophysics. Some dikes lack a strong magnetic response and do not show up at all. Ground geophysics has not been submitted for assessment work in great quantity so their quality and benefit cannot be properly assessed at this time. Some induced polarization surveying was done on Westfield Minerals Limited ground and only weak anomalies were found. This may be because the pyrite content of the mineralized zones rarely exceeds 10% to 15% and is usually less. Sulphide mineralization is not always correlative with gold mineralization. In general, geophysical methods do not figure highly as tools for gold exploration, however, they are good mapping tools. Where a gold-bearing zone can be established, if it is stratabound or stratiform, at least its general trend can be followed by magnetometer or induced polarization techniques.

STRUCTURAL GEOLOGY

The supracrustal rocks have been folded about a general east-trending axis into a synformal shape. The units north of Mishibishu Lake are generally south facing and north dipping. South of Mishibishu Lake top determinations are less clear and the possibility of several syncline-anticline folds is suggested by repetitions in lithology and changes in top direction. The intrusion of several felsic plutonic bodies into the metavolcanic-metasedimentary sequences south of Mishibishu Lake cause the structure to be somewhat more complex.

Lineaments are well developed and they will be studied in detail in order to determine their relationship to the over all structure.

Kink bands, refolded rock units, elongated minerals and clasts, slickensides, lineations, augens, and ptygmatic quartz veins all indicate extreme shearing occurred in several zones. Some clasts in the conglomerates were themselves actually kinked. At least two east-trending shear zones north of Mishibishu Lake host the main gold showings. Some offsets of stratigraphy were noted along these shears. There is also evidence that some north-trending cross structures also exist and they may prove to be important as localizers of gold mineralization.

ECONOMIC GEOLOGY

Aside from gold, the area would appear to offer less potential for other commodities. The varied mafic-intermediate-felsic metavolcanic terrain could provide some base metal targets. The area west of Macassa Creek has received some exploration for base metals in the past, but, the holdings have been small and a more comprehensive program over a larger block of ground may be more fruitful. Examinations of oxide affinity iron-rich rocks have not been encouraging due to low iron content.

There is a tungsten showing in Franchere Township which is outside the area mapped during this program. Some previous work has been done on it and perhaps more is warranted to properly assess it. The District Geologist in Wawa visited it and did some sampling of it and results will be included in the final report.

Due to no roads having been put into the area, heavy equipment has not been available to date so stripping and trenching have been restricted. Muscocho Explorations Limited has had a work permit approved and plans to lay a road into their property this fall and winter.

Gold potential is quite high in this area due to the structural complexity and well developed alteration zones mapped to date. The gold mineralization appears to be structurally controlled and can occur in any rock type given the right set of conditions. Potential for exhalative syngenetic gold deposits would appear to be low and field mapping turned up little evidence to encourage looking for this type of deposit.

Structures such as shear zones and either intersections of two shear zones or a shear zone and an impervious rock type would appear to be the places to look for favourable hydrothermal alteration. Quartz stockworks in the core of the sericitic alteration zones appear to be the most favourable setting for gold mineralization, and exploration should be directed to the search for such settings.

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S15. Gold Showings of the Mishibishu Lake Area, Thunder Bay District

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INTRODUCTION

During the 1985 field season the Mineral Deposits Section of the Ontario Geological Survey supplemented the Precambrian Section in a 1-year helicopter supported mapping program of the Mishibishu Lake greenstone belt (Bennett and Thurston 1977), and of selected mineral showings within it. The Mishibishu Lake belt was mapped at a scale of 1:15 840 (Figure 1) with selected gold showings being mapped at both 1:1200 and 1:120 scales. Surface mapping was supplemented by access to diamond-drill hole information.

The area immediately north of Mishibishu, Missi, and Katzenbach Lakes and bounded by Macassa Creek on the west, the Thunder Bay-Algoma District boundary on the east, and the granite-greenstone contact on the north (Figure 1), was selected for detailed mapping due to the presence of several gold showings which are actively being explored. The majority of the field season was spent working with geologists of the Precambrian Section in the 1:15 840 scale mapping of the Mishibishu Lake belt (Bowen, this volume). Only 3 weeks were spent mapping and sampling in the area of the Mishibishu Lake gold showings.

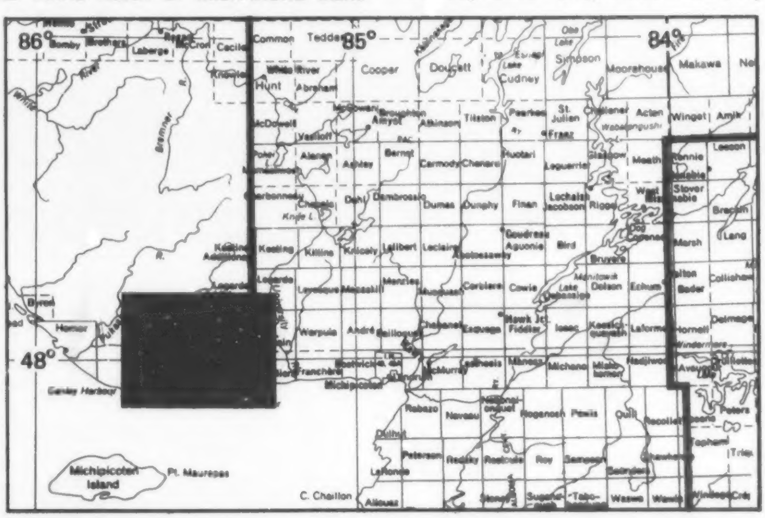
This project was made possible through in-year supplementary funding by the Government of Ontario.

MINERAL EXPLORATION

The Mishibishu Lake belt has been prospected since the late 1800s to early 1900s. Early prospectors were seeking high-grade iron formation, but their search was largely unsuccessful. There is little record of exploration in the area from the early 1900s to the middle 1930s, when prospectors obtained high gold assays from quartz veins north of Mishibishu Lake (Bennett and Thurston 1977). These became known as the Hollinger, Magnacon, and Erie Canadian (or Discovery) Showings and were extensively stripped, trenched, and blasted by Hollinger Consolidated Gold Mines Limited, Macassa Mines Limited, and Erie Canadian Mines Limited, respectively (Figure 2). In 1949, the Amichi Showing (Figure 2) was discovered by Amichi Gold Mines Limited who performed stripping, trenching, and assaying. During the summer of 1982, Westfield Minerals Limited discovered the Northwest Showing by trenching a 270 ppb gold humus anomaly (Unpublished Report 1982, Westfield Minerals Limited, Assessment Files Research Office, Ontario Geological Survey, Toronto). Between 1949 and the early 1980s, several companies have held these showings.

At present two companies, Westfield Minerals Limited and Muscocho Explorations Limited, are actively evaluating the aforementioned showings and other geological targets. Westfield Minerals Limited has conducted extensive drilling, trenching, humus geochemistry, and geophysics on all the showings. During the 1985 field season Westfield Minerals Limited completed 1000 feet of diamond drilling on their Discovery Showing (or Erie Canadian Occurrence). Muscocho Explorations Limited is engaged in an extensive diamond drilling program on the Magnacon group of showings (Figure 2) which they hope to finish by December 1985 (P. Mordaunt, Geologist, Muscocho Explorations Limited, Toronto, personal communication, 1985). To date, they have completed 16 000 feet of diamond drilling and will be adding a third drill rig (The Northern Miner Press, September 23, 1985).

Durham Resources Incorporated spent a few weeks mapping and sampling their Missing Lake and "Scuzzy Lake" properties. The only other activity ob-



LOCATION MAP **Scale : 1:1 548 000 or 1 inch to 25 miles**

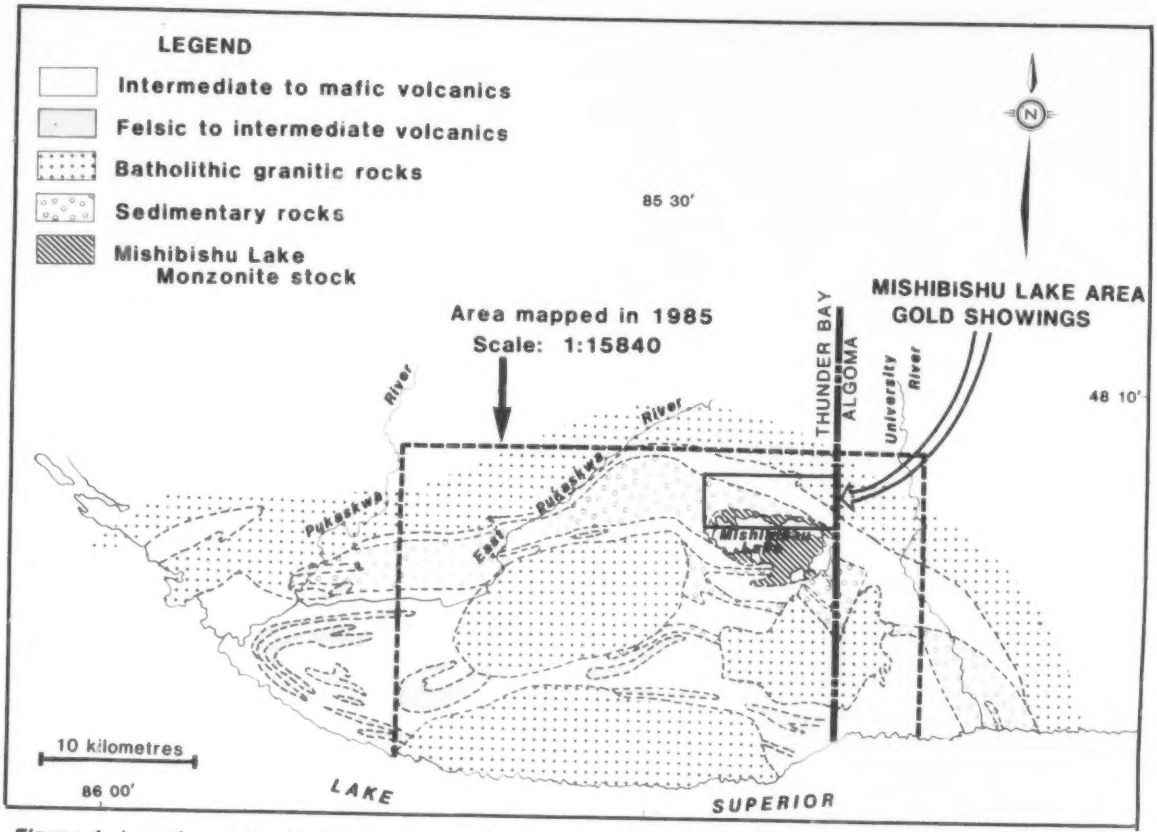

LEGEND
Intermediate to mafic volcanics
Felsic to intermediate volcanics
Batholithic granitic rocks
Sedimentary rocks
Mishibishu Lake Monzonite stock
85 30'
N
MISHIBISHU LAKE AREA GOLD SHOWINGS
Area mapped in 1985
Scale: 1:15840
THUNDER BAY
ALGOMA
University River
River
River
48 10'
Pukaskwa
East Pukaskwa
Mishibishu Lake
10 kilometres
86 00'
LAKE
SUPERIOR

Figure 1. Location of the Mishibishu Lake area gold showings and the Mishibishu Zone (small blocked area) in relation to the regional geology (simplified from Bennett and Thurston 1977). The large blocked area represents the area covered by mapping during 1985 at a scale of 1:15 840. (Project S15.)

served was that of Prospecting Geophysics (Val d'Or, Quebec) who performed line cutting and soil sampling on Granges Exploration Limited's claims located west and northwest of Mishibishu Lake. Granges Exploration Limited has optioned 42 000 acres (The Northern Miner Press, September 23, 1985) of ground surrounding the Muscocho-Westfield holdings from MacMillan Energy Corporation.

GENERAL GEOLOGY

A detailed description of the regional geology of the Mishibishu Lake belt is given by R.P. Bowen of the Precambrian Section (this volume) and by Bennett and Thurston (1977).

The general geology of the area hosting the Mishibishu gold showings is depicted in Figure 2. All the rocks in the Mishibishu Lake belt have undergone at least greenschist facies metamorphism, therefore the prefix meta- is not used subsequently. The gold showings are localized within a large geologically complex zone, herein called the 'Mishibishu Zone', which occurs between mafic volcanic rocks to the north and clastic sedimentary rocks to the south. The mafic volcanic rocks appear to be a series of basalt flows and pyroclastic tuffs. The basalt flows are massive to foliated and range from fine to coarse grained. No pillowed basalts were observed in these northern volcanic rocks, but some occur in a small lens-shaped body of mafic volcanic rocks located south of the Mishibishu Zone at Oz Lake (Figure 2). Feldspar porphyritic flows, with phenocrysts ranging from 1 to 2 cm, to in excess of 10 cm, show size gradation and provide reasonable marker units. The pyroclastics consists of mafic tuff, lapilli tuff, volcanic breccia, and crystal tuff. The basalt flows and pyroclastics are locally separated by interflow sediments. The mafic volcanic package has attained greenschist metamorphic grade except for 150 m adjacent to the major granitic batholith to the north, where amphibolite grade was attained. Occasionally felsic dikes (and/or sills) were observed within the mafic volcanic package. Numerous medium to coarse grained, massive plagioclase-hornblende "gabbroic" rocks were found within this mafic volcanic sequence. Whether these are coarse flows, dikes, and/or sills of similar composition to the volcanics, or are gabbroic to dioritic mafic intrusions is uncertain.

To the south of the Mishibishu Zone is a package of sedimentary rocks comprised of polymictic conglomerate, oligomictic quartz-granule conglomerate, wacke, subarkosic wacke, arkose, and argillite (Figure 2). The polymictic conglomerates, oligomictic quartz-granule conglomerates, and wackes grade

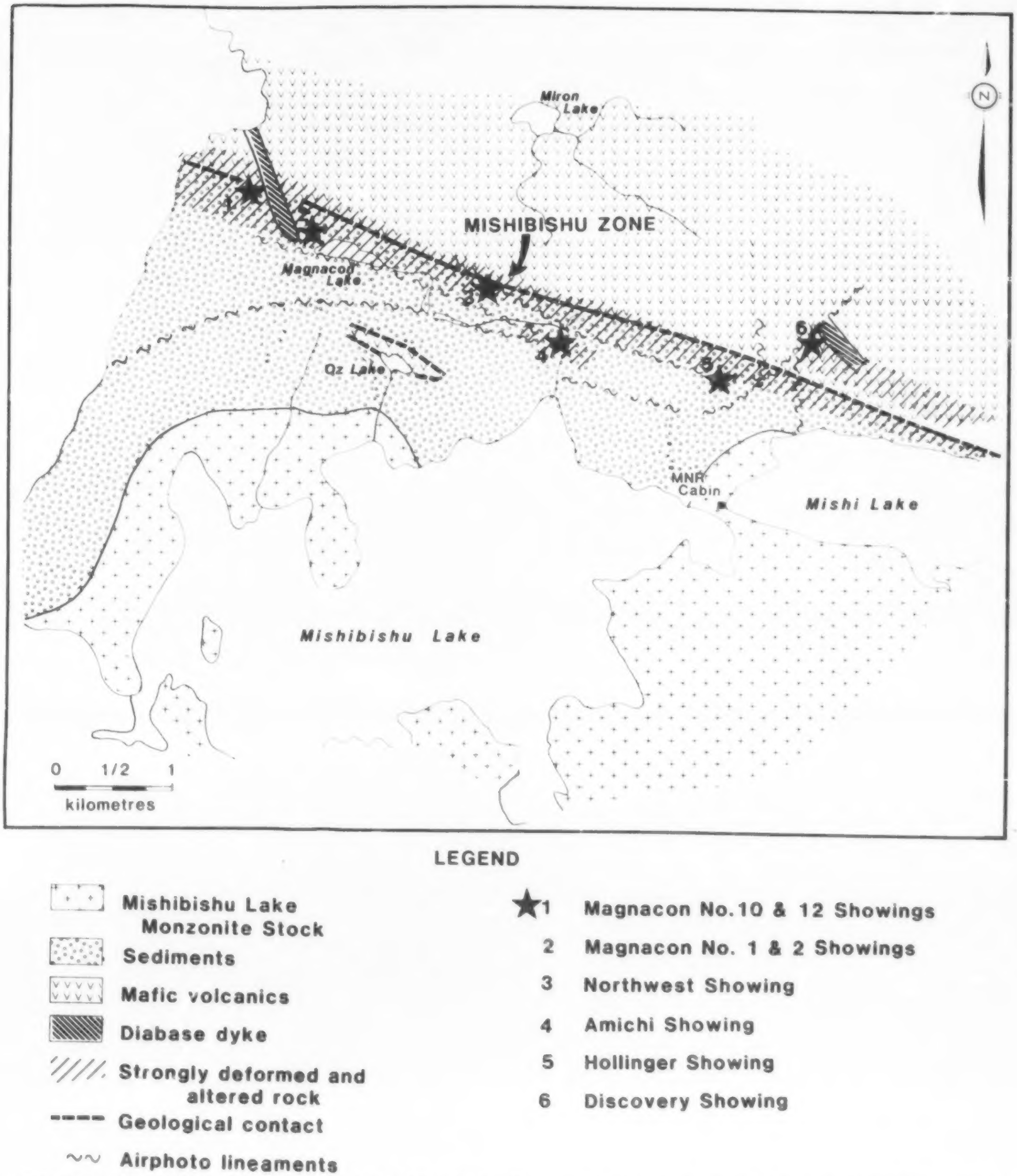

Miron Lake
N
MISHIBISHU ZONE
Magnacon Lake
Qz Lake
1
2
3
4
5
6
MNR Cabin
Mishi Lake
Mishibishu Lake
0 1/2 1
kilometres
LEGEND
Mishibishu Lake Monzonite Stock
Sediments
Mafic volcanics
▨ Diabase dyke
//// Strongly deformed and altered rock
---- Geological contact
~~ Airphoto lineaments
★1 Magnacon No.10 & 12 Showings
2 Magnacon No. 1 & 2 Showings
3 Northwest Showing
4 Amichi Showing
5 Hollinger Showing
6 Discovery Showing

Figure 2. *Simplified geologic map of the Mishibishu Zone area and location of the gold showings visited. (Project S15.)*

southward into interbedded wackes, subarkosic wackes, arkoses, and argillites which have been interpreted as a turbidite sequence.

This volcano-sedimentary package is intruded by a granitic batholith to the north, and the Mishibishu Lake monzonite stock to the south (Figure 1). Numerous diabase dikes of variable composition intrude all of the above rocks.

The northern volcano-sedimentary package of rocks which encloses the Mishibishu gold showings was interpreted by early workers as being the northern limb of a easterly plunging synclinal structure (Evans 1942; Bennett and Thurston 1977). Work this summer (*see* R. P. Bowen, this volume) indicates that a synclinal structure may exist, however, several top reversals were observed on both the northern and southern limbs, suggesting that there are minor folds that may repeat the stratigraphy. Several geochemical traverses through the volcanic rocks on both limbs, and a geochemistry-petrography study of the volcanic rocks by R. G. Reid (University of Windsor) are being conducted to address this problem. Bedding in the sediments on the north limb is overturned. Top indicators within the mafic volcanic rocks to the north are rare, with graded bedding within mafic tuffs giving conflicting top indications.

THE MISHIBISHU ZONE

The Mishibishu Zone (Figure 2) is a strongly deformed and altered, volcano-sedimentary package, which trends northwest and averages 150 m in width along its 16 km strike length. It is characterized by the development of a strong penetrative fabric, fibrous mineral growth on the penetrative fabric planes, asymmetric small-scale folds, and variable degrees of hydrothermal alteration. It is bounded to the north and south by prominent air photo lineaments, across which a significant change in degree of lithological and structural complexity occurs (Figure 2). Within the Mishibishu Zone, original rock textures (e.g. bedding) are rarely preserved except where narrow beds of polymictic pebble conglomerate can be identified within highly schistose wackes and oligomictic quartz-granule conglomerates. A strong to intense penetrative foliation is defined by layer-parallel micas. The foliation is further enhanced by compositional layering of chlorite, sericite, and quartz-ankerite segregations. The average trend of this foliation is between 115 to 120°, but in most places is variable due to later small-scale asymmetric folding (S- and Z-shaped) and tight chevron folding. These folds are locally dislocated along their axial planes, with evidence of movement being given by fibrous mineral growth and slickensides. The elongation of quartz grains and conglomerate clasts define a prominent lineation which generally plunges 10 to 50° to the north. Crosscutting the Mishibishu Zone are late brittle faults along which there appears to have been minor movement, and which are commonly occupied by diabase dikes (Figure 2). These late structures form prominent airphoto lineaments, particularly in the northwest and northeast directions.

The geometry and relative orientation of these planar and linear fabrics suggest that the Mishibishu Zone is similar to brittle-ductile shear zones described elsewhere (Ramsay and Graham 1970; Ramsay 1980; Simpson and Schmid 1983; Colvine *et al.* 1984; Hodgson 1985). However, additional work is required on the kinematics of this structurally complex zone to establish its genesis.

ECONOMIC GEOLOGY

The Mishibishu Lake belt is host to several mineral showings, including iron, gold, and base metals. Due to time constraints the only showings visited were the gold-bearing ones within the Mishibishu Zone, listed according to their level of exploration activity (Figure 2). Brief descriptions of other properties and mineral occurrences can be found in Bennett and Thurston (1977).

MAGNACON PROPERTY

The Magnacon Property discovered in the early 1930s consists of 19 patented claims which encompass the No. 1, No. 2, No. 10, and No. 12 showings (Figure 2). To date the Magnacon group of showings represents the westernmost known gold mineralization within the Mishibishu Zone. Gold mineralization occurs in two forms: within siliceous mylonites (Jim Millard, Geologist, Muscocho Explorations Limited, Toronto, personal communication, 1985) and as gold-bearing fractures within deformed quartz-ankerite veins. The mylonitic zones contain anomalous gold values (Unpublished Report 1983, Westfield Minerals Limited, Assessment Files Research Office, Ontario Geological Survey, Toronto), but are not the focus of the presently ongoing exploration by Muscocho Explorations Limited. High gold values have been restricted to quartz-carbonate veins (P. Mordaunt, Geologist, Muscocho Explorations Limited, Toronto, personal communication, 1985).

Visible gold is common and is associated with pyrite, arsenopyrite, and minor galena, chalcopyrite, and tourmaline. Alteration of the enclosing wall rocks consists of variable amounts of chlorite, sericite, quartz, green mica, ankerite, calcite, and pyrite. The gold-bearing veins are most commonly found within the sericite, green mica, and ankerite-rich areas. Higher gold assays have been obtained where a major northwest-trending structure, occupied by a diabase dike, intersects the mineralized zone.

DISCOVERY SHOWING

The Discovery Showing, discovered in 1938 (Figure 2), represents the easternmost known gold mineralization within the Mishibishu Zone. A unique feature of the Discovery Showing is that it is hosted entirely within highly altered and deformed mafic volcanic rocks. The mafic volcanic rocks outside the Mishibishu Zone consist of massive to foliated flows, and porphyritic flows with minor felsic dikes and/or sills. Within the Mishibishu Zone original textures are totally destroyed and there is intense sericitization, silicification, carbonatization, and chloritization. A crude sequence of alteration types flanking the mineralized zone was recognized during field mapping and is presented in Figure 3. Although, on the property scale, there is a progression to a sericite-quartz-rich facies adjacent to the mineralized vein system, on the outcrop scale, types (1), (2), and (3) are made up of 1 cm to 4 cm foliation-parallel segregations of the listed minerals (Figure 3). Deformation features recognized at the Discovery Showing include: a penetrative foliation along which the majority of the mineralized quartz veins were emplaced; and asymmetric S- and Z-shaped minor folding, crenulating, and kinking of that penetrative foliation and enclosed quartz veins. A second quartz vein set was observed cutting up along the axial planes of the kink folds. At this stage it is not known whether these late veins are auriferous. Gold mineralization occurs in a quartz-carbonate vein system with a strike length of approximately 120m and a variable width of 15 cm to 4 m. The vein system varies from a single discrete quartz vein over a narrow width to swarms of foliation-parallel veins over a greater width. In drill core the mineralized vein system occurs in a black "graphitic" rock which contains disseminated pyrite. This may represent a highly deformed interflow sediment or a graphitic fault zone. There is a crude zonation of the associated sulphide mineralization found within the vein system (Figure 3). Higher gold values are associated with the arsenopyrite- and galena-rich zones (B. Murphy, Geologist, Westfield Minerals Limited, Toronto, personal communication, 1985).

The Discovery vein system trends at 130° (parallel to the regional foliation) on its eastern end, but then makes an abrupt swing to almost due north (still parallel to the foliation) for the westernmost 30 m. The vein system and enclosing altered rock package appear to wrap into, and become terminated by, a fault which forms a regionally extensive airphoto lineament which strikes 055° to 060°. Adjacent to the northerly striking portion of the vein system is a small diabase dike which may have remobilized and upgraded the gold mineralization in that portion of the vein (B. Murphy, Geologist, Westfield Minerals Limited, Toronto, personal communication, 1985). The diabase dike is crenulated, bleached, and contains minor disseminated pyrite adjacent to the vein, which tentatively suggests the quartz vein system may crosscut the dike. The critical area where the dike and vein system meet is obscured by trench debris. The vein system appears to be terminated to the east by a large northwesterly trending diabase dike which forms a prominent ridge. The continuation of the black "graphitic" rock associated with the vein system, to the west of this major diabase dike, has been detected approximately 300 m to the east, by a VLF (Very Low Frequency) survey conducted by Westfield Minerals Limited (B. Murphy, Geologist, Westfield Minerals Limited, Toronto, personal communication, 1985). Drilling this summer by Westfield on this target obtained anomalous gold values (The Northern Miner Press, August 15, 1985). Westfield Minerals Limited has carried out extensive drilling of the Discovery Showing vein system.

NORTHWEST SHOWING

The Northwest Showing occurs within the northernmost 90 m of a 215 m wide zone of highly altered and deformed rock localized at a mafic volcanic-sediment contact (Figure 2). This lithologically and structurally complex zone occurs between two major airphoto lineaments, which trend approximately 115°, and is interpreted as being part of the Mishibishu Zone. The mafic volcanic rocks to the north consist of intercalated lapilli tuff, volcanic breccia, tuff, crystal tuff, massive flows, and massive, medium grained, "gabbroic" rock. To the south are interbedded polymictic conglomerates, oligomictic quartz-granule conglomerates, wackes, and arkoses which grade southward into a thick section of interbedded argillites and wackes.

As was the case for the Magnacon Property, most of the original rock textures have been destroyed, except for some clasts in the polymictic and oligomictic conglomerate units. Original bedding is locally present parallel to the penetrative foliation. Alteration types consist of chloritization, ankeritization, sericitization, silicification, and the development, locally, of a bright apple green mica (possibly fuchsite). These alteration types form bands of variable width parallel to the penetrative foliation. Within the area of mineralization the penetrative foliation has been S- and Z-folded, chevroned, and kinked. Gold mineralization occurs in narrow (<1 cm up to several centimetres), laterally discontinuous mylonitic "chert" zones (B. Murphy, Geologist, Westfield Minerals Limited, Toronto, personal communication, 1985). Thin section work by Millard (1984) has shown that these narrow siliceous zones are recrystallized and have relic cataclastic textures. Thin section work by Westfield geologists has shown these mylonitic "chert" zones to be made up of 60% to 70% quartz, 10% feldspar (orthoclase/albite/plagioclase), 10% to 20% carbonate/ankerite, up to 20% sericite with minor chlorite, and 3% to 4% disseminated pyrite (Unpublished Report 1984, Westfield Minerals Limited, Assessment Files Research Office, Ontario Geological Survey, Toronto). Locally these mylonitic zones grade laterally into more conventional bulbous quartz-ankerite vein material. These bulbous veins seem to be localized at the hinge zones of minor folds and crenulations which may have been dilatent

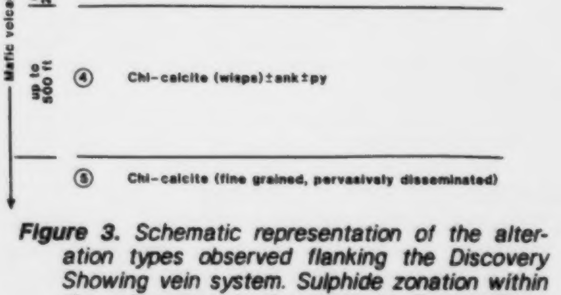

WEST
~100 m
EAST
Alteration pattern on this side of quartz vein symmetric with that shown below
Quartz vein
Qtz+gal±py ±asp±ser±chl
Qtz+asp±py±cpy ±gal±ser±chl ±ank±tour
Qtz+py±ser ±chl±asp
Qtz±py
Mafic volcanics
50 - 100 ft
up to 200 ft
up to 500 ft
① Ser+qtz+py±chl±ank±green mica (mineral bands and segregations)
② Chl+ser+qtz±ank±py (mineral bands and segregations)
③ Chl+ank±py±ser
④ Chl-calcite (wisps)±ank±py
⑤ Chl-calcite (fine grained, pervasively disseminated)

Figure 3. Schematic representation of the alteration types observed flanking the Discovery Showing vein system. Sulphide zonation within the vein system is also depicted. (Project S15.)

relative to the mylonitic zones. Numerous large discontinuous quartz-ankerite boudins were observed in trenches at the Northwest Showing, but none contained significant gold values (Unpublished Report 1984, Westfield Minerals Limited, Assessment Files Research Office, Ontario Geological Survey, Toronto). However, similar looking quartz-ankerite veins located approximately 300 m east along strike, assayed 1.57 ounces gold per ton from a grab sample, and 0.53 ounce gold per ton over 4 feet (Unpublished Report 1984, Westfield Minerals Limited, Assessment Files Research Office, Ontario Geological Survey, Toronto). Westfield Minerals Limited has carried out extensive trenching and diamond drilling on the Northwest Showing.

HOLLINGER SHOWING

The Hollinger Showing, discovered in the late 1930s, is located to the west of the Discovery Showing (Figure 2). Gold mineralization is found in highly deformed quartz-ankerite-pyrite boudins associated with quartz-chlorite-sericite schists located within the Mishibishu Zone. Gold values, although locally high grade, are sporadic (Unpublished Reports 1982 and 1984, Westfield Minerals Limited, Assessment Files Research Office, Ontario Geological Survey, Toronto). The intensity of deformation the quartz-ankerite veins have undergone is evidenced by their extremely boudinaged character and the strong development of minor folds, crenulations, and kinks within the surrounding schists. Diamond drilling by Westfield Minerals Limited returned anomalous gold values associated with narrow zones of highly deformed quartz-ankerite-sericite schist (Unpublished Report 1984, Westfield Minerals Limited, Assessment Files Research Office, Ontario Geological Survey, Toronto). A major northeast-trending diabase dike, similar to the ones found on the Magnacon and Discovery Showings, cuts across the Hollinger Showing.

AMICHI SHOWING

The Amichi Showing is the southernmost of the known gold showings (Figure 2). Gold mineralization occurs in a 25 to 90 cm wide quartz-ankerite-pyrite ± galena ± chalcopyrite vein within highly deformed and altered wacke, arkose, and argillite. Trenching by Westfield Minerals Limited produced some high-grade gold values over very narrow widths (B. Murphy, Geologist, Westfield Minerals Limited, Toronto, personal communication, 1985). Diamond drilling below the surface mineralized vein failed to intersect a comparable major quartz vein (Unpublished Reports 1982 and 1984, Westfield Minerals Limited, Ontario Geological Survey, Toronto). Limited fieldwork this summer indicates the Amichi Showing is located on a small subsidiary deformed zone off but subparallel to the Mishibishu Zone.

SUGGESTIONS FOR EXPLORATION

1. The Mishibishu Zone is localized at a mafic volcanic-sediment contact. However, mapping at the Discovery and Amichi Showings suggests that there may be subsidiary deformation zones developed entirely within volcanic rocks or sediments.
2. The Mishibishu Zone has not been delineated to the west of the Magnacon Showing or to the east of the Discovery Showing, but regional scale mapping has indicated areas of coincident alteration and deformation in these areas.
3. Favourable alteration minerals are sericite, green mica, ankerite, pyrite, chlorite, and quartz. Gold-bearing veins are most commonly associated with sericite-green mica altered rocks.
4. Higher gold values are associated with quartz-ankerite ± pyrite ± arsenopyrite ± galena ± chalcopyrite veins.
5. Due to the overall low sulphide content of the mineralized veins and the presence of non-auriferous pyrite-pyrrhotite bodies, geophysical methods may not be applicable. Humus geochemistry has proven useful for locating drill targets to date.
6. In places, delineation of major structures which cross the Mishibishu Zone, may help locate areas favourable for gold mineralization. Commonly, these cross-structures are occupied by large diabase dikes.
7. Sound geological and structural mapping, in conjunction with major mechanical outcrop stripping, will provide essential information in this complex area.

ACKNOWLEDGMENTS

Brendan Murphy, Alex Marr, and Terrance McKillen of Westfield Minerals Limited; and Peter Mordaunt, Jim Millard, and Duncan McPhee of Muscocho Explorations Limited, are acknowledged for their unabridged cooperation. Finally, I would like to thank the numerous individuals who helped during the course of the field season.

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16. Goudreau-Lochalsh Area, District of Algoma

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INTRODUCTION

As part of the continuing mapping program of the Wawa area (Sage 1984, Figure 1) parts of five townships were mapped (Figure 1). Mapping of all of Abotossaway, Aguonie, and Bird Townships was completed and most of Finan and Jacobson Townships were mapped.

MINERAL EXPLORATION

ABOTOSSAWAY TOWNSHIP

Mapping was concentrated in the northwestern and northern parts of the township. Access is by abandoned logging and mine development roads. Some of the more isolated areas are accessible by canoe and portage.

Two major areas of mineralization occur. One area of mineralization is found on the Ego Resources Limited property in central Abotossaway Township. Mineralization consists of fractures filled with coarse grained chalcopyrite and pyrite carrying significant gold values. These fractures occur in supracrustal rocks within the hornfelsed contact aureole of the trondhjemitic Gutcher Lake Stock.

The second area of mineralization is the Murphy Mine located in east-central Abotossaway Township. Gold in a quartz-carbonate vein has been the object of numerous exploration efforts during the past 60 years. Visible gold can still be found on the dump. The Murphy Mine quartz-carbonate vein occurs in hornfelsed intermediate to mafic metavolcanics intruded by quartz-feldspar porphyry associated with the Gutcher Lake Stock.

Other gold showings, such as the Farquahar 'Vein', occur on the south flank of the Gutcher Lake Stock.

Known gold mineralization mapped this year within the area of Abotossaway Township appears to be closely associated with the Gutcher Lake Stock and occurs as veins and fracture fillings within the hornfelsed contact aureole of the stock.

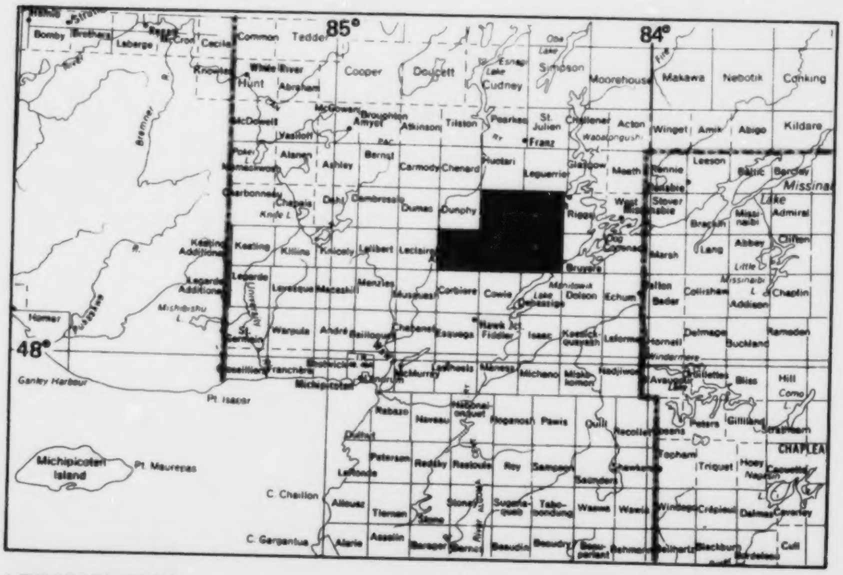
Evidence of old and recent prospecting activity occurs throughout the township.

The Ego Resources Limited (formerly Ego Mines Limited) property had a stated reserve of 300 000 tons grading over 2% copper and 0.07 ounce gold per ton based on diamond drilling done between 1964 and 1966 (Canadian Mines Handbook 1978-79, p.108). The property was optioned to United Canso Oil and Gas Limited in 1976 which completed additional trenching, diamond drilling, and underground development. Revised reserve estimates are not available.

The Murphy Mine had a reported production of 2450 ounces gold and 351 ounces silver from 23 211 tons (Mineral Deposit Files, Ontario Geological Survey, Toronto (MDF). Grade was 0.11 ounce per ton with 65% recovery. Reserves are given as 60 000 tons at $11.20 per ton ($35.00 ounce) (MDF).

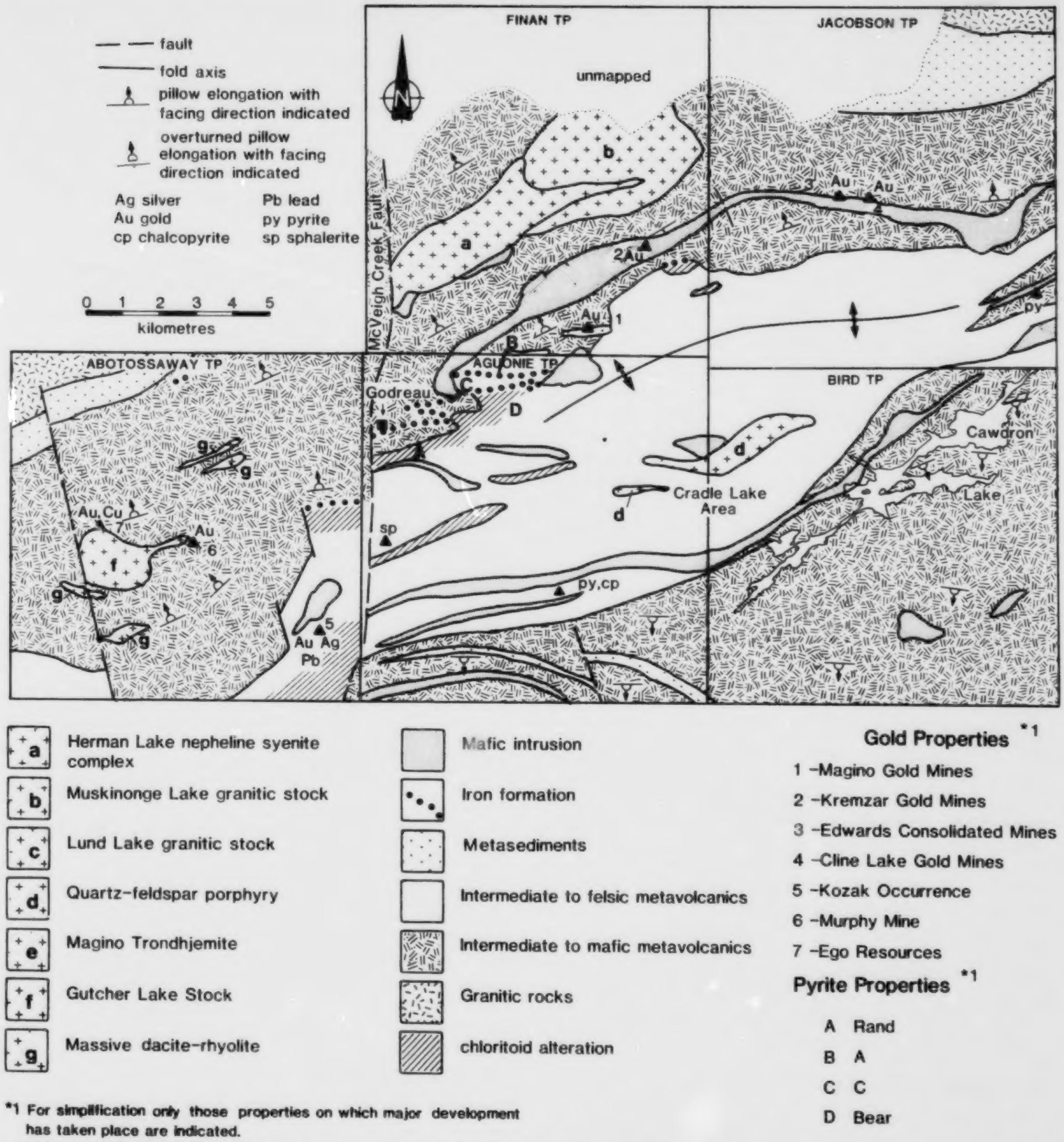
AGUONIE TOWNSHIP

Mapping was concentrated in the northwestern and northeastern corners of Aguonie Township. Access to the area is by the Goudreau-Lochalsh road and various logging access roads. Previous exploration in this area was concentrated on sulphide facies iron formation. Some of these pyrite deposits have been previously mined for their pyrite. Mined deposits are the Rand No.1, Bear, "A", and "C". Production from these deposits is unknown and mining activity was short lived.


85°
84°
48°
Common
Tedder
Cooper
Doucett
Cudney
Simpson
Moorehouse
Makawa
Nebotik
Conking
White River
Hunt
Abraham
McDowell
Vasiliof
Atkinson
Tilston
St. Julien
Franz
Acton
Winget
Kildare
Ashley
Bernst
Carmody
Chenard
Leguerrier
Leeson
Missinaibi
Lake
Admiral
Chapais
Dumas
Dunphy
Riggs
Killins
Lallibert
Marsh
Clifton
Corbiere
Cowie
Dolson
Echum
Chaplin
Michipicoten Island
Pt. Maureias
Pt. Isacor
Gantey Harbour
C. Chaillon
C. Gargantua
Peterson
Restoule
Roy
Sampson
Wawa
Windego
Triquet
Cull
CHAPLEAU
Hill
Como
Buckland
Ramsden

LOCATION MAP

Scale : 1 : 1 548 000 or 1 inch to 25 miles


fault
fold axis
pillow elongation with facing direction indicated
overturned pillow elongation with facing direction indicated
Ag silver
Au gold
cp chalcopyrite
Pb lead
py pyrite
sp sphalerite
0 1 2 3 4 5
kilometres
FINAN TP
JACOBSON TP
ABOTOSSAWAY TP
AGUONIE TP
BIRD TP
unmapped
McVeigh Creek Fault
Godreau
Cradle Lake Area
Cawdron Lake
Au, Cu
Au Ag Pb
py,cp
sp
py
a
b
c
d
f
g
A
B
C
D
1
2
3
4
5
6
7
a Herman Lake nepheline syenite complex
b Muskinonge Lake granitic stock
c Lund Lake granitic stock
d Quartz-feldspar porphyry
e Magino Trondhjemite
f Gutcher Lake Stock
g Massive dacite-rhyolite
Mafic intrusion
Iron formation
Metasediments
Intermediate to felsic metavolcanics
Intermediate to mafic metavolcanics
Granitic rocks
chloritoid alteration
Gold Properties *1
1 –Magino Gold Mines
2 –Kremzar Gold Mines
3 –Edwards Consolidated Mines
4 –Cline Lake Gold Mines
5 –Kozak Occurrence
6 –Murphy Mine
7 –Ego Resources
Pyrite Properties *1
A Rand
B A
C C
D Bear

*1 For simplification only those properties on which major development has taken place are indicated.

Figure 1. Sketch map of geology encountered in the map area. (Project 16.)

Significant gold or base metal mineralization is unknown in Aguonie Township but the rocks are highly favourable for such mineralization.

Union Miniere Exploration and Mining Corporation Limited examined several geophysically indicated conductive zones for base metals in 1975 and 1976.

BIRD TOWNSHIP

Mapping covered the central, northern, and eastern margins of Bird Township. Access is by a rough road to Cawdron Lake in central Bird Township and then by canoe and portage to the more isolated areas. Bush covered trenches and diamond drill set-ups were located in a number of areas. The diamond drill set-ups tested conductive zones. This work was completed in 1976 by Union Miniere Exploration and Mining Corporation Limited (Assessment Files Research Office, Ontario Geological Survey, Toronto, (AFRO).

A gold showing occurs on the southern shore of Cawdron Lake. The showing consists of gold in pyrite which may be in fact be a very narrow band of iron formation approximately 0.3 m wide. This showing was diamond drilled in the 1930s but has not been subjected to recent investigation.

FINAN TOWNSHIP

Mapping up to the present has covered in excess of 70% of Finan Township with efforts being concentrated along the tracks of the Algoma Central Railway and along logging access roads north and south of the Goudreau-Lochalsh road.

Numerous gold showings occur along the Goudreau-Lochalsh road and the area has been subjected to intense prospecting in the past. The principal gold showings are that of the Magino Gold Mines Limited and that of Canamax Resources Incorporated on the Kremzar property. Recent work in the area has concentrated on previously known gold showings. The Magino Gold Mines Limited property produced 8776 ounces gold and 856.0 ounces silver from 116 627 tons of ore when the property was known as the Algoma Summit Gold Mine (MDF). The mine is reported to contain estimated reserves of 200 000 tons grading 0.33 ounce gold per ton (The Northern Miner Press; 1983, Volume 64, Number 21, p.3).

Work on the Kremzar property by Canamax Resources Incorporated has outlined drill indicated reserves of 870 000 tons grading 0.23 ounce gold per ton (The Northern Miner Press; 1985, Volume 71, Number 27, p.3).

Shortly after the turn of the century and again in the 1950s and 1960s a number of iron formations were diamond drill tested. The later drilling was by Algoma Ore Properties Limited which investigated the deposits as sources of pyrite. None of the pyrite properties were placed into production. Minor but subeconomic gold mineralization was encountered in diamond drilling of the Morrisson No.1 pyrite deposit (not shown on Figure 1). This mineralization occurs in fractures crosscutting the iron formation. The township has been examined for base metal deposits by Amax Exploration Incorporated.

JACOBSON TOWNSHIP

Mapping within Jacobson Township is currently 85% complete and was concentrated along the Goudreau-Lochalsh road, the tracks of the Canadian Pacific Railway, and various logging access roads. Numerous gold occurrences occur in proximity of the Goudreau-Lochalsh road and two showings have recorded gold production. The former producing properties were known as the Cline and Edwards properties.

The Cline Mine has a recorded production of 63 328 ounces gold and 10 598 ounces silver from 331 842 tons of ore and the Edwards 484 ounces gold and 37 ounces silver (MDF). Reserves at the Cline were given as 20 000 tons at $20.00 per ton in 1967 (MDF). Both the Cline and Edwards properties have been subjected to considerable exploration activity (AFRO).

Vega Gold Explorations Incorporated has recently conducted an extensive drill program for gold in eastern Jacobson Township.

The township has been explored by many companies for base metal deposits. Two of the more intense efforts were by Gulf Minerals Canada Limited and Amax Exploration Incorporated.

GENERAL GEOLOGY

ABOTOSSAWAY TOWNSHIP

Abotossaway Township was previously mapped by Bruce (1940) in the 1930s.

The part of Abotossaway Township examined this season is dominantly underlain by intermediate to mafic metavolcanics. These rocks consist of massive and pillowed units and a minor quantity of mafic tuff and breccia.

The intermediate to mafic metavolcanics are intruded by mafic rocks of quartz diorite to gabbro composition and felsic rocks of trondhjemite to dacite composition. The largest intrusion is the Gutcher Lake Stock of trondhjemite composition located in west-central Abotossaway Township. The Gutcher Lake Stock is enveloped in an aureole of metavolcanics that have been contact metamorphosed to the hornblende hornfels rank (Studemeister 1985).

South, east, and northeast of the Gutcher Lake Stock elongate masses of fine grained intermediate to felsic rocks have concordantly intruded the metavolcanics.

The metavolcanics have been metamorphosed to the greenschist facies rank.

Along the northern margin of the supracrustal assemblage a band of metasediments separates the external granites from the metavolcanics. This band of metasediments is very poorly exposed. It is up to 1 km wide, and consists of siltstone, wacke, and Dore-type conglomerates. As the northern margin of the supracrustal belt is approached, the metamorphic grade rapidly increases to amphibolite facies rank. This change in metamorphic rank generally occurs within 1 km of the contact.

AGUONIE TOWNSHIP

South of the Goudreau-Lochalsh road the metavolcanics are dominantly intermediate to felsic in composition. They consist of breccia, lapilli-tuff, feldspar crystal tuff, tuff, and quartz-feldspar crystal tuff. Locally, near iron formation, chloritoid is commonly present in the intermediate to felsic rocks.

A unit of iron formation, consisting of limestone or siderite, pyrite, and chert, occurs along the contact between the intermediate to felsic rocks and intermediate to mafic rocks. The iron formation in the Goudreau area has an identical facies distribution to that of the Wawa area. Calcite, however, replaces siderite in some of the Goudreau iron ranges.

The intermediate to mafic metavolcanics lying above the iron formation consist of chlorite schist, massive and pillowed flows, and rare tuff and breccia.

Both the mafic and felsic rocks have been intruded by intermediate to mafic intrusions that vary from quartz diorite to gabbro in composition.

Two elongate masses of fine grained trondhjemite intrude the supracrustals at the Magino property.

The metavolcanics mapped in Aguonie Township are metamorphosed to greenschist facies rank and are moderately carbonated.

BIRD TOWNSHIP

Mapping in Bird Township outlined the eastern extension of the intermediate to felsic metavolcanics described for Aguonie Township. In central and southern Bird Township, the rocks consist of intermediate to mafic metavolcanics. These rocks are massive, pillowed, and schistose.

A narrow band of wacke was partly outlined in the southwestern corner of the township. This metasedimentary band was previously described by Sage (1984) and extends south and beyond the map area.

Quartz-feldspar porphyry intrusions uncovered in the previous season (Sage 1984) extend eastward into Bird Township. Numerous intermediate to mafic intrusions of quartz diorite to gabbro composition cut the intermediate to mafic or felsic metavolcanics.

The rocks were metamorphosed to the greenschist facies rank of regional metamorphism and locally the rocks display pervasive carbonate alteration.

FINAN TOWNSHIP

Only minor quantities of intermediate to felsic metavolcanics were encountered in Finan Township. Rocks of this composition are part of the intermediate to felsic section exposed in Aguonie Township to the south.

Iron formation, which is part of the same unit found in Aguonie Township, lies in contact with the intermediate to felsic metavolcanics. On the opposite side of the iron formation, metavolcanics of intermediate to mafic composition can be found. These rocks consist of pillowed, massive, and schistose units.

Numerous intrusions of intermediate to mafic composition intrude the supracrustal rocks. These intrusions vary from quartz diorite to gabbro in composition.

The rocks are metamorphosed to the greenschist facies rank of regional metamorphism and locally display carbonate alteration.

JACOBSON TOWNSHIP

Mapping encountered minor quantities of intermediate to felsic metavolcanics in central Jacobson Township which are the eastern extension of similar rocks in Aguonie and Bird Townships to the west and south.

Most of the rocks consist of pillowed, massive, and schistose intermediate to mafic metavolcanics. Intermediate to mafic tuffs, lapilli-tuff, and rare breccia are locally present.

Quartz diorite and gabbro intrude the supracrustal sequence. Quartz diorite intrudes the supracrustal rocks near the former Cline Mine and quartz diorite is common near the eastern margin of the township.

Along the northern margin of the supracrustal sequence, thin bedded wackes and siltstones separate the intermediate to mafic metavolcanics from the external granites.

Metamorphic rank is of greenschist facies that increases rapidly to amphibolite facies rank near the contact with the external granites.

STRUCTURAL GEOLOGY

ABOTOSSAWAY TOWNSHIP

On the basis of top determinations, the stratigraphy both south and east and north and east of the Gutcher Lake Stock faces north, towards the external granites.

The linear lakes north, east, and south of the Gutcher Lake Stock reflect bedrock structure and perhaps shear zones. Where outcrop is found at the end of these linear lakes it is commonly fissile and pervasively soaked with carbonate. Diabase dikes commonly occupy a northwest-trending fracture system.

AGUONIE TOWNSHIP

Facing data is lacking in the intermediate to felsic rocks. On the basis of pillow shape, the stratigraphy north of the iron formation faces north throughout the area mapped.

The distribution of the iron formation suggests tight folding is present which is not readily apparent within the surrounding rocks.

Shearing, commonly at a low angle to lithologic strike is common in the area.

Aguonie Township is separated from Abotossaway Township to the west by the north-south striking McVeigh Creek Fault. This fault is characterized by a deep valley presently occupied by the tracks of the Algoma Central Railway. Hills rise steeply east and west from the valley.

BIRD TOWNSHIP

On the basis of pillow shape, the stratigraphy in central and southern Bird Township faces south. In the intermediate to felsic metavolcanics of northern Bird Township, facing data are lacking.

The long linear lakes in the area reflect bedrock control, possibly shearing which generally strikes parallel to subparallel to lithologic trends.

FINAN TOWNSHIP

On the basis of pillow shapes, the stratigraphy faces north. The northern and eastern extension of the iron formation from Aguonie Township suggests the continuing presence of tight folding.

Shearing is common throughout the area. This shearing is commonly parallel to subparallel to lithologic trends. A north to slightly west of north regional cross fault occurs near the eastern margin of the township.

JACOBSON TOWNSHIP

On the basis of pillow shape, the stratigraphy faces north. Locally, the rocks display shearing parallel to subparallel to lithologic trends.

Along the northern margin of the belt, deformation of the granites has produced mylonitic textures.

The marginal metasediments are sheared and locally tightly folded. Well-developed chevron folding is common in some outcrops of metasediments.

ECONOMIC GEOLOGY AND RECOMMENDATIONS TO PROSPECTORS

The rocks throughout the area are highly favourable for gold and base metals and have been subjected to several exploration efforts for base metal mineralization.

The area offers excellent potential for gold. The area from Goudreau to Lochalsh contains numerous gold showings and several properties have been past producers. The potential for gold deposits beneath the sand and gravel that covers wide areas is excellent and is essentially untouched by previous exploration efforts. The development of geochemical and overburden drilling techniques as prospecting tools for the area need to be undertaken.

Re-examination of known gold showings is warranted. The recent development of a potentially economic gold deposit on the Kremzar property is the result of a recent evaluation of a previously examined and diamond drilled gold showing.

The iron formations within the area mapped this past season are unlikely to be profitably mined for their iron contact. The iron formations represent a large potential source for pyrite provided economics justify its extraction.

Gold is known to occur in crosscutting fractures but not in the iron formation itself.

Gold occurs with chalcopyrite and pyrite in fractures in supracrustals enclosing the Cutcher Lake Stock, in quartz-carbonate veins at the Murphy mine, and in carbonated and silicified shear zones at the Magino, Kremzar, and Cline properties.

Gold mineralization in the Goudreau-Lochalsh area displays strong structural control. The gold mineralization is associated with carbonate alteration and silicification. Trace to minor pyrite may occur with the gold.

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S17. Hearst-Kapuskasing Area, District of Cochrane

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This project was funded by the Ministry of Natural Resources under the Special Projects to Assist Resource Communities (SPARC) Program.

INTRODUCTION

The Hearst-Kapuskasing area covers 1075 km^2 between Latitudes 49°07′05″N and 49°19′05″N, and Longitudes 82°52′30″W and 83°45′W. The map area covers all of Caithness, Rykert, Fergus, and Ecclestone Townships, and part of Scholfield, Pelletier, Doherty, Abbott, Opasatika and Bourinot Townships (Figure 1). The towns of Hearst and Kapuskasing, major supply points on Highway 11, are equidistant 60 km from the central part of the map area.

From Hearst the western third of the area can be accessed via Highway 682 south to the Caithness forest access road. Numerous logging roads in various stages of repair provide access to the western third of the area. The Goat and Mattawitchewan Rivers provide water access in parts of Pelletier, Scholfield, and Caithness Townships.

From Kapuskasing the eastern two-thirds of the area is accessible by the Fergus Lake Road or by the Cargill-Bourinot forest access road. Major internal access routes include the Ecclestone and Abbott forest access roads. Several logging roads off these access roads cover most of the area. The Missinaibi and Opasatika Rivers provide north-south access across the central and eastern parts of the map area.

Topographic relief averages 3 to 5 m throughout the map area with maximum relief approximately 30 m in Doherty Township. Much of the area is covered by lacustrine clay, and large parts of the map area, especially in the north, have little or no outcrop.

MINERAL EXPLORATION

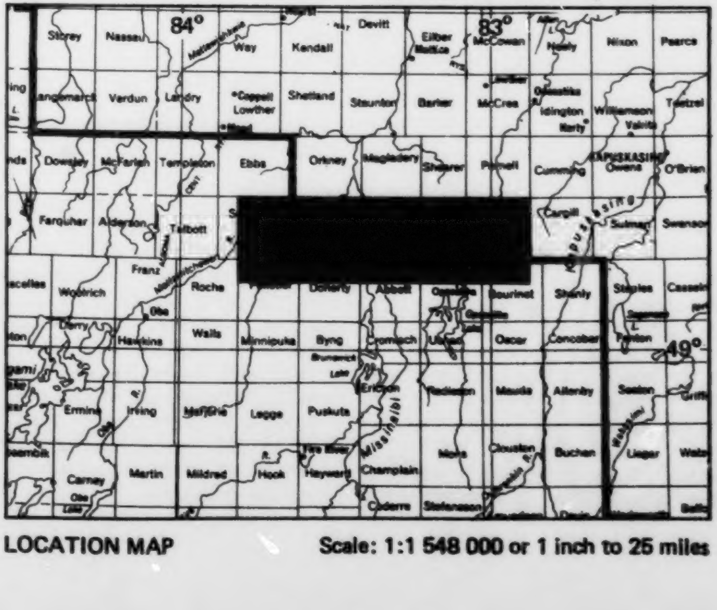
According to the Assessment Files Research Office (AFRO), Ontario Geological Survey (OGS), Toronto, and the Resident Geologist's Files, Ontario Ministry of Northern Affairs and Mines, Timmins, there has been limited exploration in the map area. Lundberg Explorations Limited carried out airborne electromagnetic and magnetic surveys over part of Caithness and Rykert Townships in 1959. The company carried out ground geophysical surveys, but no diamond drill targets were generated.

In Ecclestone Township, Kenogamisis Gold Mines Limited carried out ground geophysical surveys in 1964. Several electromagnetic conductors were diamond drill tested and returned only pyrite-pyrrhotite mineralization.

The Cargill Township phosphate-vermiculite deposit under option to Sherritt Gordon Mines Limited is associated with a carbonatite intrusion east of the map area (Sage 1983a). Initial exploration by Continental Copper Mines Limited in 1954 extended into Ecclestone Township, but subsequent exploration efforts have been centered on the intrusion. Currently an on-site, portable mill is testing 6000 to 7000 tons of ore as part of an ongoing development program (D. Mackinnon, Sherritt Gordon Mines Limited, personal communication, 1985).

GENERAL GEOLOGY

The main purpose of the Hearst-Kapuskasing Project is to provide a better definition of the supracrustal rocks mapped by Bennett *et al.* 1967. The 1985 field work indicates that the metavolanics generally conform to the distribution defined in 1967, but with several important deviations. In Pelletier and Doherty Townships, the mafic metavolcanics extend west and north of the previously defined contacts, and are composed of massive to pillowed flows intermixed with pillow breccias and tuffaceous rocks. An important change to the previous mapping is the discovery of a felsic pyroclastic unit overlying the mafic metavolcanics and pelitic metasediments along the southern contact of the supracrustal rocks. The pyroclastics are composed of felsic ash tuffs, lapilli


84°
83°
49°
Storey
Nassau
Way
Kendall
Devitt
McCowan
Nixon
Pearce
Langemarck
Verdun
Landry
Lowther
Shetland
Staunton
Barker
McCrea
Idington
Williamson
Dowsley
McFarlan
Templeton
Ebbs
Orkney
Magladery
Shearer
Cumming
KAPUSKASING
O'Brien
Farquhar
Alderson
Talbott
Cargill
Sulman
Swanson
Wybrich
Franz
Roche
Doherty
Abbott
Opasatika
Bourinot
Shenly
Staples
Hawkins
Walls
Minnipuka
Byng
Cromlech
Oscar
Concobar
Fenton
Ermine
Irving
Legge
Puskuta
Rodolph
Maude
Allenby
Seaton
Carney
Martin
Mildred
Hook
Hayward
Champlain
Clouston
Buchan
Missinaibi
Kapuskasing

LOCATION MAP Scale: 1:1 548 000 or 1 inch to 25 miles

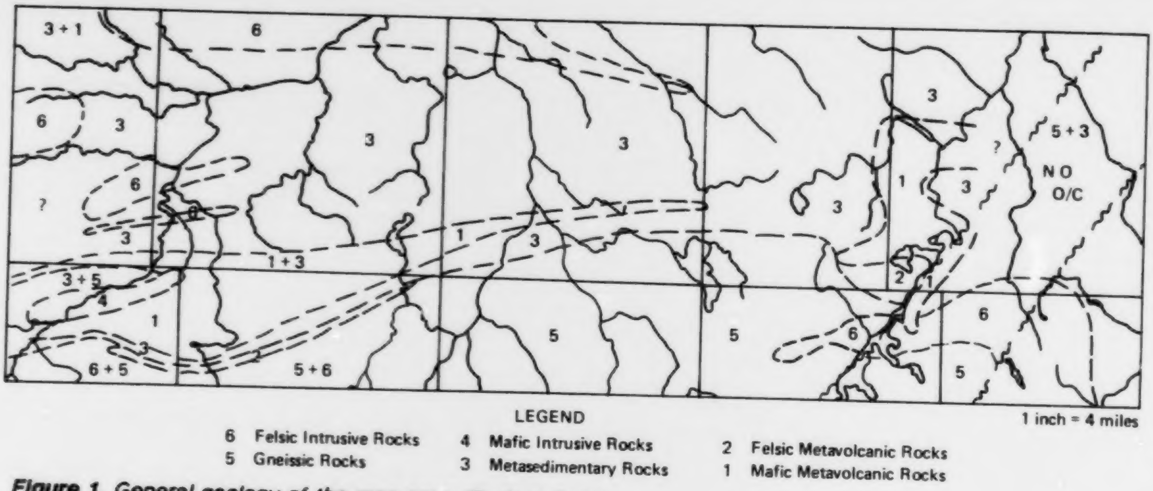


Figure 1. *General geology of the map area. (Project S17.)*

tuffs, and pyroclastic breccias interbedded with tuffaceous metasediments. Quartz "eyes" up to 2 mm diameter are common, as are felsic bombs up to 20 cm diameter. Sulphide fragments are occasionally present, and where the felsic unit is partly assimilated by pegmatite in Pelletier Township, molybdenite occurs. The unit is mappable eastward from Pelletier Township for 13 km, before it becomes intercalated with clastic metasediments.

In Doherty Township, field evidence does not support the northeasterly striking dextral fault previously interpreted by Bennett *et al.* 1967. The distribution of lithologies and structural measurements suggests that folding of the units is a more probable mechanism of deformation in this area.

The mafic metavolcanics were mapped as a continuous linear unit from Pelletier Township through Doherty, Caithness, and Rykert Townships to north of Buchanan Lake, where the unit disappears under overburden. Mafic metavolcanics appear 10 km further east near the Opasatika River, but whether or not they represent the same unit is uncertain. Mafic metavolcanics at Rufus Lake and Flatt Lake are considered equivalent with those at Opasatika River, and are composed mainly of ash tuffs and pyroclastic breccias with minor flows. The mafic metavolcanics do not extend into Bourinot Township, as shown on the 1967 map, rather they are fault rotated or folded entirely within Ecclestone Township. In the Flatt Lake - Rufus Lake area a quartz-feldspar porphyry to granodiorite has intruded the mafic metavolcanic unit. The intrusion may be equivalent to the felsic metavolcanics in Pelletier and Doherty Townships, but this correlation is uncertain.

The other major supracrustal lithology in the map area is clastic metasediments. These rocks are predominantly turbiditic wackes with minor interbedded amphibolitic metasediments, chert, tuffaceous metasediments, and sulphide-magnetite facies iron formations. In the northern part of the area the sedimentary rocks are monotonous and show little vertical or lateral variation, except near their contact with the mafic metavolcanics, where they are interbedded with mafic flows or pillow breccias. The clastic metasediments along the southern contact of the mafic metavolcanics are mainly turbiditic wackes, but appear to be more pelitic than the northern metasediments. They are often porphyroblastic with garnet, alumino-silicates, and possibly staurolite. This unit is often interbedded with felsic tuffs.

Several small plutons have intruded the supracrustal rocks. The most significant of these is a hornblende monzonite to diorite intrusion in Pelletier Township. The pluton is approximately 16 km long and up to 6 km wide, and appears to have extrusive equivalents along strike to the east.

The geology south of the supracrustal rocks is composed of various granitic intrusive rocks and gneisses, and is divisible into two distinct domains. The southwestern domain is composed predominantly of massive, white weathering, granitic pegmatite with subsidiary orthogneiss, tentatively identified as assimilated felsic metavolcanics. The pegmatite occurs as large mappable units exhibiting crude mineral zonation. As the supracrustal contact is approached from the south, massive pegmatite composed essentially of quartz, feldspar, and biotite grades into pegmatite mixed with orthogneiss, and develops garnet plus fibrolitic sillimanite mixed with muscovite. Pegmatites, intruded into the supracrustal rocks and adjacent to the supracrustal granitic contact, concentrate tourmaline, molybdenite, and possibly uranium minerals.

The southeastern domain is predominantly gneissic ranging from recognizable ortho- and paragneisses to metatexites, which have unrecognizable protoliths, but preserve the regional foliation observed in the supracrustals, to diatexites which have unrecognizable protoliths and develop gneissosity in response to local stresses. The progression from ortho-paragneiss to metatexite to diatexite appears to develop southward from the supracrustal rocks. Tonalitic to granodioritic plutons intruding the gneisses are foliated, exhibit gradational contacts, and are considered to be syn-tectonic, but are still younger than the gneisses.

Diabase dikes intrude all rock types. The principal orientation of the dikes is 340° with secondary clusters at 045° and 075-090°. The latter set of dikes are usually foliated subparallel to the diabase contacts. In the map area the dike sets exploited structural weaknesses created by a deformational event responsible for the refolding of the supracrustal rocks.

STRUCTURAL GEOLOGY

The geology in the map area records at least two recognizable periods of deformation. Clastic metasediments east of Fergus Lake display classic interference fold patterns with F_2 axes striking approximately 045°. In Pelletier and Doherty Townships similar interference patterns were observed with F_2 axes striking 320° to 340°. The pattern of mineral and intersection lineations is subparallel to mesoscopic F_2 axes, and is well developed in the supracrustal rocks within 1 km of the supracrustal-gneissic contact. The gneissic rocks do not generally develop lineations, but where present, they are parallel to the lineations in the supracrustal rocks, indicating the gneisses were involved in the deformation. In the F_2 fold closures, transposition of units is observed, which prohibits development of a reliable stratigraphy, or correlation of units in areas of poor outcrop. The second deformation is responsible for folding the supracrustal-gneissic contact. Nowhere in the map area does this contact exhibit brittle failure.

The first deformational event is inferred to have isoclinally folded the supracrustal rocks about subvertical axes. A westerly plunging syncline mapped in Caithness and Scholfield Townships is inferred to represent a D_1 fold which has been modified by D_2 so that dips are substantially less than vertical. The mineral and intersection lineations developed by D_1 are predominantly east-west, and their presence in the rocks is most noticeable at distances greater than 1 km from the supracrustal-gneissic contact.

Brittle deformation is evident along a northeast-trending fault line cutting Rufus Lake and part of the Opasatika River. There is a marked change in structure across the fault from east-striking, north-dipping attitudes on the west side of the fault, to north-striking, east-dipping attitudes of the rocks on the east side of the fault. Rocks along the fault line are crushed and in places appear mylonitic. It is possible the fault represents an F_2 hinge line which has failed brittlely; however, the juxtaposition of clastic metasediments and well developed gneisses further north indicates that significant vertical slip has occurred.

The supracrustal rocks appear to have been metamorphosed to the upper greenschist facies and probably to the lower amphibolite facies of regional metamorphism. The mafic metavolcanics usually consist of hornblende-plagioclase assemblages, commonly with garnet and biotite, chlorite is normally absent. The clastic metasediments are composed of quartz, plagioclase, and biotite with accessory garnet and hornblende. More pelitic rocks are often porphyroblastic with alumino-silicates, garnets, and possibly staurolite. There is no substantial preservation of low grade metamorphic rocks in the map area. Numerous contaminated pegmatites and xenoliths of felsic orthogneiss in the western part of the map area contain garnet and radiating aggregates of fibrolitic sillimanite and muscovite, indicating amphibolite grade metamorphism. The gneissic rocks in the eastern part of the map area are quartz, feldspar, hornblende, and biotite assemblages with few mesoscopic metamorphic indicators, except for poorly developed garnets.

ECONOMIC GEOLOGY

No occurrences of base or precious metals are known within the map area; however, the area has been poorly explored and undiscovered mineral deposits may be present. The 1985 mapping program has identified several geological environments which may host economic mineralization.

The felsic pyroclastic unit in Pelletier and Doherty Townships is considered to be a favourable target for base and precious metal mineralization, and because it has been partly assimilated by pegmatites and metamorphosed to gneiss, the area south of the unit also warrants further attention.

The area between Flatt Lake and Rufus Lake in the eastern part of the map area is composed of mafic tuffaceous rocks intruded by quartz-feldspar porphyry to granodiorite. In the vicinity of the Rufus Lake dam the porphyry is sheared to a quartz-muscovite schist, and is intermixed with sulphide-rich tuffs and metasediments. Sulphide and epidote-bearing quartz veins intruded along shear planes where the porphyry is less deformed. Precious metal and possibly base-metal mineralization is favoured in this environment.

The area of Ecclestone Township west of the Opasatika River and south of the Ecclestone forest access road, is underlain predominantly by mafic to intermediate pyroclastic breccias, with minor debris flows, pillowed flows, and minor iron formation. Cherty fragments are common in the debris flows and occasionally sulphide fragments are present. This environment warrants prospecting as it does not appear to have been previously explored.

The map area has numerous sulphide-magnetite showings, which occur as stratigraphic horizons interlayered with mafic flows or clastic metasediments. Most of the showings contain pyrite with accessory pyrrhotite or graphite, and minor chalcopyrite. In Pelletier Township, about 1 km west of the 54 km marker on the Caithness Road, rusty mafic tuffs, clastic metasediments, and iron formation are complexly folded and now form a 250 m thick section of gossan containing pyrite and graphite. Although no economic assays were returned (3 ppb gold, <2 ppm silver, 57 ppm copper, 630 ppm zinc average from 2 grab samples, results by Geoscience Laboratories, Ontario Geological Survey, Toronto), only a small part of the unit was sampled, and economic zones may be present.

In Fergus Township immediately south and east of Fergus Lake several cherty sulphide-rich iron formations are present. Sulphide concentration varies from 5% to 95% and in thickness from 0.6 to 3 m. Pyrite, pyrrhotite, and graphite are the major minerals present with lesser quantities of magnetite and quartz. This area is complexly deformed, and transposition of units is common, resulting in short strike lengths and apparent thickening of originally long, thin horizons.

In the central part of Caithness Township, 800 m east of the Mattawitchewan River, a massive pyrrhotite showing is hosted in mafic tuffs and derived metasediments. The showing, noted by Bennett *et al.* 1967, consists of approximately 3 m of massive sulphide mineralization, overlain by chert and underlain by graphitic sediments. Assays are low (2-3 ppb gold, <2 ppm silver, 18-26 ppm copper, and 209-630 ppm zinc, average from 3 grab samples, results by Geoscience Laboratories, OGS); however, much of the immediate vicinity is clay covered and the strike extension has not been explored, according to available assessment records.

The numerous massive pegmatites and associated pegmatite veins in the western part of the map area may host economic minerals. The pegmatite is composed of quartz, alkali and plagioclase feldspar, with biotite and/or muscovite, and is considered to have formed by anatexis of the felsic metavolcanics and clastic metasediments. Where the assimilation of the supracrustal units is less complete, garnet and fibrolitic sillimanite are present. Near the contact of the supracrustals with the pegmatite, tourmaline, molybdenite, and possibly, uranium minerals are present. This last phase of pegmatite development, warrants close examination for its economic potential.

A pegmatite vein, approximately 500 m east of Rufus Lake, contains large (up to 1.5 m) alkali feldspar crystals, and about 30% biotite. The biotite occurs as large books 5 to 50 cm in length, with an average thickness of 5 mm, which may be commercially viable.

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S18. Geology of the Havilland - Goulais Bay Area, District of Sudbury

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This project was funded by the Ministry of Natural Resources under the Special Projects to Assist Resource Communities (SPARC) Program.

INTRODUCTION

The centre of the map area is located 38 km north of the City of Sault Ste. Marie. It includes parts of Fenwick, Havilland, Kars, Ley, Tupper, and VanKoughnet Township and is bounded by Latitudes 46°45'00"W and 46°52'30"N and Longitudes 84°15'00"W and 84°30'00"W.

Highway 17 traverses the central part of the map area in a northerly direction. This highway and a network of paved and gravel roads provides good access to almost all parts of the map area.

MINERAL EXPLORATION

The information reported here, if not stated otherwise, is taken from assessment files, Resident Geologist Office, Sault Ste. Marie. The Sill Lake Silver Mine in VanKoughnet Township is the only producing mine in the area. Present production is from a decline with several stopes at a rate of 100 tons per day with a grade of 12 ounces of silver per ton and 10% lead (The Northern Miner, December 1, 1983).

Mineral exploration for copper and silver in the area dates back to about 1890 with shaft sinking and tunnelling at the Tribag Goulais River property in VanKoughnet Township and shaft sinking at the Lucinda Gold Mines Limited property in Fenwick Township.

A manganese occurrence located near Horseshoe Bay in Ley Township was explored in 1942 by Chromium Mining and Smelting Company Limited with trenching and diamond drilling (11 holes for a total of 633 m). The grade and tonnage outlined was too low to be of economic interest at this time.

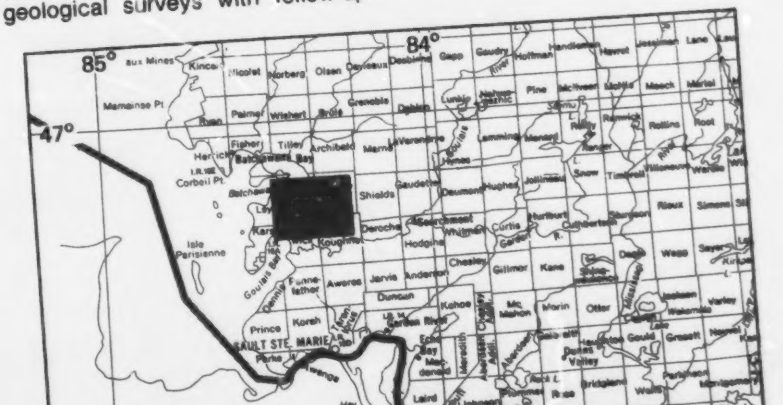
During the period from 1954 to 1964 ground geophysical and geological surveys with follow-up drilling (11 holes for a total of 665 m) were carried out by Pitch-Ore Uranium Mines Limited in the Wolfe Lake area (east of the map area), and by Ontario Rare Metals Limited in the Bone Lake area in Tupper Township. Airborne geophysical surveys were carried out over the eastern half of Tupper Township by Technical Mine Consultants Limited in 1956.

From 1964 to 1985 most exploration activity in the map area was centred in VanKoughnet Township. Geological, geophysical and soil geochemical surveys on the Goulais River copper-silver property were conducted by Airnorth Mines Limited and later by Tribag Mining Company Limited between 1970 and 1973. Airnorth Mines Limited diamond drilled two holes for a total of 141 m, Tribag Mining Company Limited put down 19 holes for a total of about 2000 m.

Diamond drilling by Tribag Mining Company Limited on the Sill Lake property in 1973 led to the discovery of a high-grade argentiferous galena vein. Ground geophysical surveys and more diamond drilling (for a total of 1090 m) followed from 1979 to 1981. In 1981, 120 m of underground development resulted in a decline reaching a depth of 30.5 m. Full scale production at the current rate began in 1984. Sill Lake Silver Mines Limited is presently developing a second underground level and installing a surface spiral concentrator.

GENERAL GEOLOGY

The first geological mapping of the area was done by McConnell (1927). Subsequent and more detailed mapping in adjacent areas was done by Hay (1964), Bennett (1975), Frarey (1977), Russell (1982), and Giblin (1982a,b).



Scale: 1:1 548 000 or 1 inch to 25 miles

LOCATION MAP

The map area is underlain by Archean supracrustal and plutonic rocks; Early Proterozoic supracrustal and intrusive rocks; Middle Proterozoic (Keweenawan) supracrustal rocks; and supracrustal rocks of probable Paleozoic (Cambrian) age.

The Archean rocks form an east-west trending metavolcanic-metasedimentary sequence. These consist of intercalated, pillowed to massive mafic and intermediate metavolcanic flows and intermediate and felsic pyroclastic rocks with minor wackes, cherts and ironstones. There are three cycles in the succession all with proximal felsic pyroclastic rocks and associated chert-ironstone horizons. These lithologies are mainly found in Fenwick Township and south of Sill Lake in VanKoughnet Township.

Near Havilland and Probwyn Lakes, the middle part of the Archean volcanic sequence consists mainly of intermediate pyroclastic rocks and minor flows intercalated with minor mafic metavolcanic units. This is overlain by a sequence consisting mainly of pillowed and minor massive mafic metavolcanics which are intercalated in the upper part with minor quartz-biotite metawackes. The upper part of the Archean volcanic sequence strikes in a east-west direction across Havilland and Tupper Townships.

Medium- to coarse-grained gabbro-diorite dikes and sills are common throughout the entire metavolcanic sequence. These rocks are most abundant in the mafic lower and upper parts of the sequence. Plagioclase-porphyritic diabase dikes and possibly some younger Nipissing diabase dikes also intrude the metavolcanics. The dikes and sills are from 10 to 400 m thick. In places they are conformable with the metavolcanics, in others they are crosscutting.

Archean felsic plutonic and minor felsic migmatite rocks underlie most of Tupper and part of Havilland Townships. The felsic plutonic rocks consist of coarse-grained, weakly foliated, biotite-bearing quartz diorite, tonalite with minor granodiorite and granite. Migmatites which occur near Havilland Bay and north of Tupper Lake contain potassic feldspar augen, and are intruded by felsic dikes of three ages.

The felsic plutonic and migmatitic rocks are commonly intruded by northwesterly striking diabase dikes which are abundant near Tupper and Picard Lakes. Northeasterly trending dikes are found only north of the King Mountain plateau.

Early Proterozoic rocks of the Huronian Supergroup, namely the metasediments of the Gowganda and Lorrain Formations (Cobalt Group) occur in the southern half of the map area.

The Gowganda Formation rocks are approximately 1500 m thick and consist mainly of a basal unit of granitic cobble-pebble conglomerate overlain by thinly bedded mudstones and siltstones grading upward into mudstones and arkoses which in turn are overlain by an upper arkose unit. Ripple marks and size grading were observed and indicate current directions from the east. The contact between the Gowganda and overlying Lorrain Formations is poorly exposed and in places may be faulted.

Rocks of the Lorrain Formation have a thickness of 750 m in the King Mountain plateau. A smaller outlier occurs near Goulais Bay at Kars Creek. The formation consists of white, massive arkosic quartzarenite containing in places quartz pebble beds, red, massive quartzarenite and a quartz-jasper pebble conglomerate unit which represents the upper part of the Lorrain Formation (Frarey 1977). Minor size grading occurs in some pebbly beds.

A prominent east-west striking sill (1000 m thick) of Early Proterozoic Nipissing quartz diabase intruded the rocks of the Gowganda Formation in the vicinity of King Mountain. This diabase is traceable for a distance of 7 km across the southern part of VanKoughnet Township.

Amygdaloidal basalts and minor polymictic conglomerates of Middle Proterozoic (Keweenawan) age are exposed along the shore of Lake Superior near Jones Creek and east of Horsehoe Bay. The conglomerate clasts consist of sub-rounded to rounded cobbles of Archean granite, Lorrain Formation quartzarenite, Gowganda Formation siltstones and Keweenawan basalt set in an arkosic wacke matrix.

Clastic sedimentary rocks of the Jacobsville Formation of probable Cambrian age underlie most of the areas near Kars Creek, Havilland Bay, and Goulais Bay. The Jacobsville Formation consists mainly of red to red-brown coloured, thinly bedded feldspathic arenites with minor conglomerates and siltstones. The arenites exhibit mottling with white circular spots and irregular white blotches and streaks. The conglomerate is poorly indurated and is comprised of angular to sub-angular cobbles and pebbles of quartzarenite derived from the Lorrain Formation, Gowganda Formation siltstone and Keweenawan basalt. The Jacobsville conglomerate is similar in composition to the nearby Keweenawan conglomerate. The Keweenawan conglomerates are somewhat more consolidated and contain more rounded clasts than the conglomerates of the Jacobsville Formation.

STRUCTURAL GEOLOGY

An early east-west trending anticline is indicated by a reversal of tops in the Archean pillowed mafic volcanic rocks along the southern margin of the map area. The volcanic rocks south of Sill Lake are southward facing, however throughout the rest of the area the tops are uniformly northward facing and form a steeply-dipping monoclinal sequence. The upper part of the Archean volcanic sequence near Evans and Belleau Lakes in Tupper Township is folded into a dome-like structure which was probably caused by the squeezing of the volcanic sequence between bodies of felsic plutonic rock during diapiric emplacement.

The sediments of the Gowganda and Lorrain Formations have a uniform northerly dip of 25-45°. They possibly represent the erosional remnant of the southern limb of an east-west trending flat syncline. The northern limb was presumably destroyed by erosion.

Folding of Keweenawan rocks along a north-south axis has resulted in dips of 20-50°W. The rocks of the Jacobsville Formation generally dip westward at angles of 05°-30° (Giblin 1982a).

Throughout the map area, several major faults and shear zones have been identified. One of the shear zones trends north-east and is located just south of Bone Lake within Archean felsic plutonic rocks. Quartz veining, brecciation, chloritization and minor pyrite mineralization are associated with this shear zone.

Several northeast-trending *en echelon* shear and fault zones cut both the Archean metavolcanic and intrusive rocks and the mudstones of the Gowganda Formation. The fault has downdropped the rocks of the Gowganda Formation adjacent to Archean metavolcanics and probably localized the lead-silver mineralization at Sill Lake Mine and the copper-silver mineralization at the Goulais River property.

Three major post-Cambrian fault zones have been recognized along the southern and western margins of the map area and along the eastern coastal area of Havilland Bay. Rocks of the Jacobsville Formation have been affected by these fault zones. The westward extension of the VanKoughnet fault of Giblin (1982b) separates the Cambrian Jacobsville Formation from all older strata. A fault that separates the rocks of the Gowganda and Lorrain Formations from Archean metavolcanic rocks in the Kars Creek-Goulais Bay area is associated with this fault. Strong cataclasis, brecciation, and chloritization are well developed at several localities along these post-Cambrian fault zones, as for example, near Havilland Bay and along the VanKoughnet fault in Fenwick Township.

ECONOMIC GEOLOGY

Silver and lead vein mineralization at the Sill Lake Mine is along the contact of a steeply dipping gabbro-norite dike and mudstones of the Gowganda Formation, but not in contact with the main Nipissing quartz diabase sill at this location. The gabbro-norite dike is compositionally different from the Nipissing diabase as it contains relicts of pyroxene and pseudomorphs of olivine. It is less altered than Nipissing diabase.

The argentiferous galena quartz-carbonate vein which varies from .3 to 1 m in width has ore grades of 40 ounces of silver per ton and 10-30% lead. Sulphide minerals present are galena, tetrahedrite, pyrite, chalcopyrite, sphalerite, and pyrrhotite (Robinson 1977). Important factors controlling the mineralization are believed to be the proximity to Archean pillowed mafic volcanic rocks and several northeast-trending faults. It is not known what role, if any, the diabases that are spatially associated with the deposit played in the origin of the mineralization.

A similar geological setting exists at a sphalerite-galena showing near Highway 17 in Fenwick Township. Quartz-carbonate veins are hosted in gabbroic rocks near a till-covered argillite-gabbro contact. Only trace amounts of gold, and silver were indicated by assays (Assessment Files, Resident Geologist's Office, Sault Ste. Marie). Potential exists for lead, silver and zinc mineralization south of several pits located along this diabase-argillite contact. Additional exploration work, such as drilling, is recommended for the area.

The Goulais River copper-silver property is located to the south of Sill Lake in VanKoughnet Township where copper and silver mineralization is hosted in sheared Archean metavolcanic rocks. A steeply dipping, carbonate and graphite-bearing breccia zone extends over a strike length of 850 m. The mineralized zone contains pyrite, pyrrhotite, and chalcopyrite and has a width of 2 to 5 m. Diamond drilling outlined approximately 250 000 tons grading 2.35% copper and 0.26 ounces silver/ton (The Northern Miner, June 13, 1973). Additional copper and silver mineralization may occur to the east of the property in VanKoughnet Township where the north-easterly extension of the main mineralized shear zone is located. This area is recommended for further prospecting and exploration.

Manganese mineralization occurs as manganite in carbonate filled fractures in the 10-15 m wide, reddish flow top breccia of a Keweenawan basalt just east of Horseshoe Bay in Ley Township. The zone which is 400 m long and trends northerly was diamond drilled at intervals of 15 to 30 m. Average assays returned less than 2% MnO_2 with best results of 2.9% MnO_2 over 8.2 m.

Sulphide mineralization consisting of several minor pyrite occurrences within sheared Archean felsic plutonic, migmatitic and pyroclastic rocks and mafic metavolcanic rocks occur throughout the map area. Although these occurrences are minor, further prospecting could result in the discovery of economic base metal deposits.

Ironstone occurs interbedded with Archean felsic metavolcanic rocks in Fenwick Township. The units vary from 3 to 20 m in thickness and consist of interbedded chert-magnetite ironstone, chert-hematite ironstone and minor limonite. These lithologies are mainly of interest for their gold potential.

No gold occurrences have been reported in the map area. The geological environment, however, is favourable for gold mineralization within the Archean metavolcanic rocks in Fenwick Township. Some of the important features which define target zones for future detailed prospecting, geological mapping and sampling are:

(1) intensely carbonatized and/or silicified zones
(2) ironstone, chert or pyritic chert horizons
(3) felsic pyroclastic units
(4) areas of abundant quartz veining and/or shearing within the Archean metavolcanic rocks.

Commercial quarrying of sand and gravel occurs at four pits located within the map area, and peat and peat moss deposits are located in low-lying areas near Highway 17 in Fenwick Township.

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S19. Tofflemire, Venturi, and Vernon Townships, District of Sudbury

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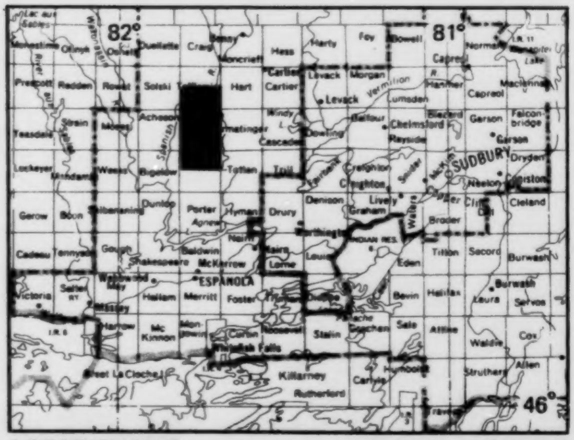
This project was funded by the Ministry of Natural Resources under the Special Projects to Assist Resource Communities (SPARC) Program.

INTRODUCTION

Tofflemire, Venturi, and Vernon Townships are located between 52 and 66 km west-northwest of the City of Sudbury. Maintained gravel roads from Cartier and Windy Lake on Highway 144 provide access to Fox Lake Lodge, located at the northern end of Fox (formerly Macauley) Lake. A network of old logging roads permits access by four-wheel drive and ATC vehicles to most parts of the area lying south and east of the Spanish River. Secondary and logging roads leading northward from Webbwood on Highway 17 provide access to those parts of Tofflemire Township which lie north and west of the Spanish River.

The geology of Venturi Township, the southern half of Tofflemire Township, and the northern half of Vernon Township has not previously been mapped. The results of earlier mapping programs to the north, east, and south of the current project area indicate a predominantly granitic terrain containing a series of outliers of Huronian metasediments which form an arcuate belt concentric about the North Range of the Sudbury Structure (Card 1978; Card and Innes 1981; Choudhry 1984). The belt may represent a graben which controlled the deposition of, or simply preserved, the Huronian metasediments (Figure 1).

The current program was instituted in order to ascertain the distribution of Huronian rocks in the remaining unmapped part of this belt of outliers. Such outliers would be expected to include rocks of the Lorrain Formation, which is thought to have the potential to contain sedimentary gold mineralization similar to that contained in the Witwatersrand Basin in South Africa (Colvine 1981), and rocks of the Espanola Formation, which locally contains skarn deposits of magnetite, zinc (with minor copper, lead, cobalt, and nickel), and tungsten. The Spanish River Carbonatite Complex is located in northeastern Venturi and southeastern Tofflemire Townships and has been prospected in the past for vermiculite, apatite, and niobium (Sage 1983). The current program also addresses the possible genetic relationships between the belt of Huronian metasedimentary outliers and the Spanish River Carbonatite Complex with the Sudbury Structure.



LOCATION MAP

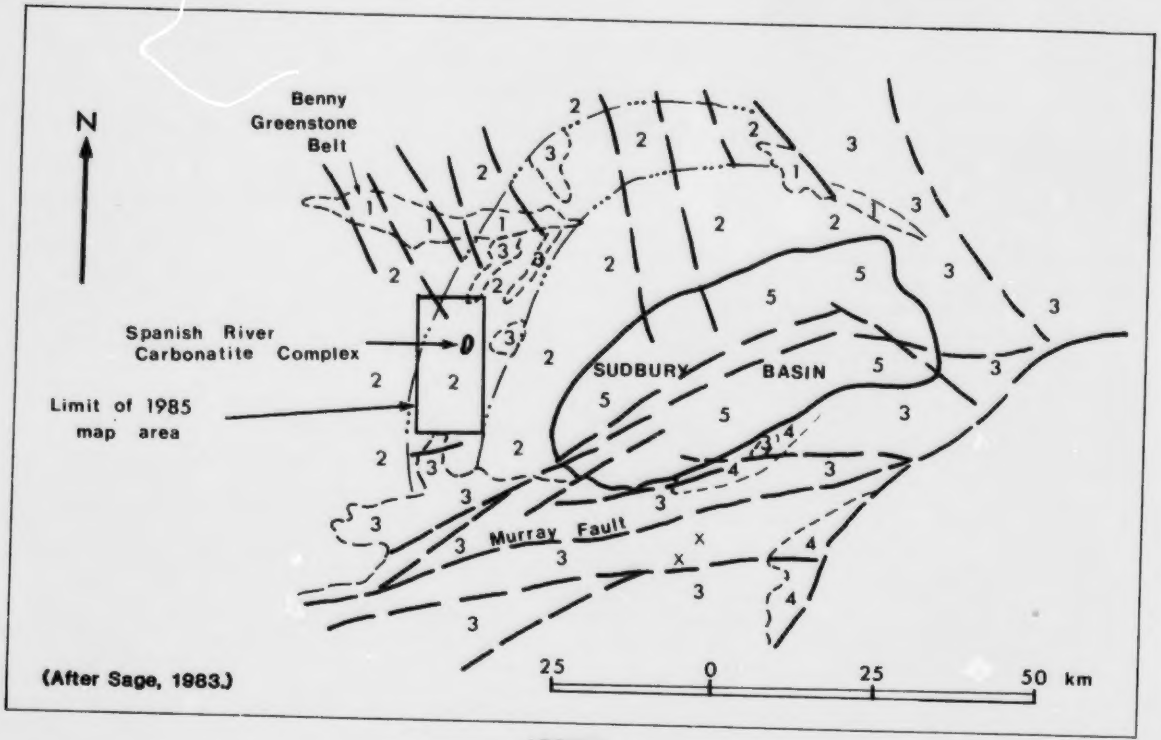
Scale : 1 : 1 548 000
or 1 inch to 25 miles

MINERAL EXPLORATION

Mineral exploration within the map area has been restricted to the Spanish River Carbonatite Complex which has been prospected for tin, vermiculite, niobium, and residual apatite (Assessment Files Research Office, Ontario Geological Survey, Toronto (AFRO).

In 1955, Canadian Johns-Manville Company Limited performed magnetometer and geological surveys directed towards the occurrence of vermiculite which was thought to be the weathering product of biotite. The carbonate rocks were thought to be metasediments and were not recognized as carbonatites at that time. In 1957, a syndicate headed by E. Eaton of Sudbury completed a number of bulldozer trenches on the property. In 1960, Jenmac Company Limited performed further bulldozer trenching and sampling for vermiculite. Guillet (1962) reported that the best concentrations of vermiculite occurred in marble adjacent to amphibolite dikes. He also noted that early reports of the presence of tin had not been confirmed by subsequent work. In 1968, Union Carbide Canada Limited drilled a single inclined diamond-drill hole to a depth of 1736 feet (529.3 m) to test for the presence of pyrochlore. Minor pyrochlore, chalcopyrite, pyrite, and pyrrhotite were observed. The core was tested for copper, cobalt, nickel, vanadium, and niobium but no significant results were obtained. In 1975, the International Minerals and Chemical Corporation (Canada) Limited conducted magnetometer, seismic, and radiometric surveys and completed four reverse circulation drillholes for a total of 822 feet (250.5 m) to test for niobium, rare earth elements, copper, and titanium. No significant values were obtained. Six leased claims are currently held over the carbonatite body by Ike Burns Exploration Corporation of Sudbury, Ontario.

No exploration work has been reported from other parts of the current project area which was hitherto unmapped. The location of the Spanish River Carbonatite Complex and of three minor mineral occurrences detected by field party personnel are shown in Figure 2.



LEGEND

Proterozoic
X Lusk Lake and Nemag Lake fenites
5 Sudbury Igneous Complex
4 Creighton Pluton
3 Huronian metasediments and Nipissing diabase

Archean
2 Felsic Intrusive rocks and migmatite
1 Supracrustal rocks

—— Fault
– – – – Geological Contact
— ··· — Area containing isolated outliers of Middle Precambrian rocks – possible graben

Figure 1. Regional geologic setting of the map area. (Project S19.)

GENERAL GEOLOGY

The regional setting of the current map area is shown on Figure 1. The area is part of the Superior Province of the Canadian Shield and is largely underlain by felsic intrusive rocks. The western edge of the Sudbury Igneous Complex is 12 km to the east of the map area, the Benny Greenstone Belt lies some 12 km to the north, and the Murray Fault Zone passes 20 km south of the map area.

Outliers of Huronian metasediments and the Spanish River Carbonatite Complex lie within a possible graben structure which strikes northward along the western side of the Sudbury Structure. The graben may be a branch off the Murray Fault Zone. It is not clear whether this structure has simply preserved the outliers of Huronian strata or if it is an ancient feature which controlled deposition of the Huronian sediments. It may also represent ring fractures genetically related to the Sudbury event, an endogenic explosion or meteorite impact.

A simplified geological map of Tofflemire, Venturi, and Vernon Townships is shown in Figure 2. Most of the map area is underlain by felsic intrusive rocks of Late Archean age. These granitic rocks have been intruded by three suites of diabase believed to be of Late Archean, Early Proterozoic (Nipissing type), and Middle Proterozoic age (olivine diabase). Five small outliers of Early Proterozoic clastic sediments and carbonates occur in the eastern half of the map area. These constitute parts of the Matinenda, Bruce, Espanola, Serpent, Gowganda, and Lorrain Formations of the Huronian Supergroup and form part of a belt of outliers indicated by previous workers lying within the inferred graben structure described above. Sudbury Breccias are common and have been observed cutting granitic rocks, the Gowganda and Espanola Formations, and diabase. Small lamprophyre dikes are relatively common in northern Venturi and southern Tofflemire Townships. The Spanish River Carbonatite Complex is represented by a single outcrop in northeastern Venturi Township.

Outcrop is moderate in the more elevated parts of northern Venturi and southern Tofflemire Townships where the local relief reaches 150 m, but is

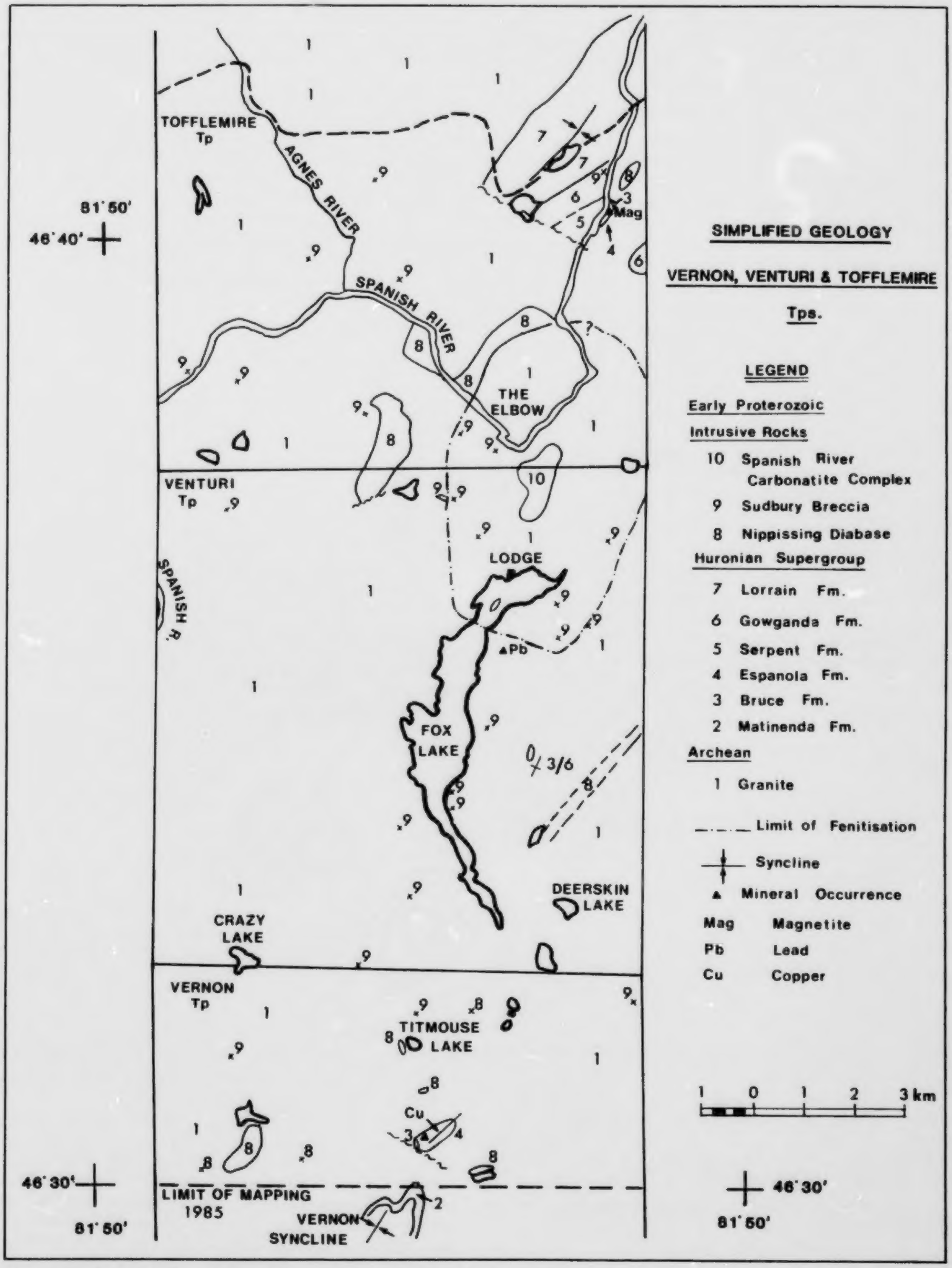

SIMPLIFIED GEOLOGY
VERNON, VENTURI & TOFFLEMIRE Tps.
LEGEND
Early Proterozoic
Intrusive Rocks
10 Spanish River Carbonatite Complex
9 Sudbury Breccia
8 Nippissing Diabase
Huronian Supergroup
7 Lorrain Fm.
6 Gowganda Fm.
5 Serpent Fm.
4 Espanola Fm.
3 Bruce Fm.
2 Matinenda Fm.
Archean
1 Granite
Limit of Fenitisation
Syncline
▲ Mineral Occurrence
Mag Magnetite
Pb Lead
Cu Copper
1 0 1 2 3 km
TOFFLEMIRE Tp
VENTURI Tp
VERNON Tp
AGNES RIVER
SPANISH RIVER
SPANISH R.
THE ELBOW
LODGE
FOX LAKE
DEERSKIN LAKE
CRAZY LAKE
TITMOUSE LAKE
LIMIT OF MAPPING 1985
VERNON SYNCLINE
81°50'
46°40'
46°30'
3/6
?

Figure 2. Simplified geology of Vernon, Venturi, and Tofflemire Townships. (Project S19.)

poor in the southern half of the map area where deposits of glacial till are extensive. Fluvioglacial sands, gravels, and eskerine deposits occupy a tract of low ground extending southwards from the Spanish River in eastern Tofflemire Township, through Fox Lake, and beyond the southern boundary of the map area.

ARCHEAN

Felsic intrusive rocks which underlie most of the map area form part of the Cartier Batholith and represent magmatic intrusions emplaced some 2500 Ma or more ago at intermediate crustal levels following the major deformation and regional metamorphism of the Kenoran Orogeny (Van Schmus 1965; Stockwell *et al.* 1970).

The predominant rock type is a massive, pink coloured, medium- to coarse-grained, equigranular granite or quartz monzonite, composed of potassium feldspar, plagioclase, and quartz with 1% to 2% hornblende or, less frequently, biotite. Phenocrysts of potassium feldspar are common and may reach several centimetres in length. Several varieties of granite were observed, characterized by variations in colour, grain size, the amount of mafic minerals present, the amount of quartz, the presence or absence of porphyritic textures, and the presence of local alteration or deformation features. Pegmatitic phases are common, aplitic phases less so. Both represent rest differentiates of the enclosing granitic rocks.

The distribution of various phases of granite is complex, often gradational and apparently random. However, in part of southeastern Venturi Township, a fine- to medium-grained, salmon pink coloured, biotitic granite is the dominant granitic phase.

Inclusions of biotite gneiss were observed near Crazy Lake, and of amphibolite east of Fox Lake. The inclusions have sharp margins bordered by pegmatitic granite.

A nonpenetrative cataclastic foliation is locally present in some massive granitic rocks. Such granites commonly contain chlorite along fracture planes, and quartz veins up to 2 m in width are often found in these areas.

Diabase

Diabase dikes believed to be of Late Archean age are widely distributed throughout the map area. Most are small, <5 m wide, are fine grained, and green to dark green in colour. They may contain scattered cubes of pyrite and in places are magnetic. Their contacts with the enclosing granitic rocks are commonly sheared and are locally calcareous.

A second type of diabase thought to be of Archean age is very fine grained to aphanitic, grey-green in colour, and contains plagioclase phenocrysts up to 4 cm in length. It is not a common rock type and is usually found in dikes <1 m wide.

Many of the Archean diabase dikes are oriented approximately east-west.

EARLY PROTEROZOIC

Huronian Supergroup

Five outliers of Early Proterozoic metasediments occur in the map area (Figure 2). The largest outlier occurs in east-central Tofflemire Township. It consists of an asymmetrical syncline whose axis trends northeast-southwest. The northwestern limb of the syncline contains only rocks of the Lorrain Formation, mapped previously by Card and Innes (1981), while the southeastern limb, mapped during the current program, contains at least parts of the Bruce Formation, the Espanola Formation, possibly the Serpent Formation, the Gowganda and Lorrain Formations. The structure is limited to the southwest by a major fault oriented at 130°, and to the southeast by strike faults oriented at 025°. On the northwestern limb, Card and Innes (1981) described a sedimentary contact between granitic basement and basal siltstone of the Lorrain Formation. The Lorrain Formation is some 400 to 500 m thick and consists of arkose, sericitic arenite, pebbly sandstone, and conglomerate. It is underlain by approximately 300 m of polymictic paraconglomerate, arkose, sandstone, and siltstone of the Gowganda Formation which is well exposed west of the Spanish River. On the eastern shore of the Spanish River is a narrow belt of thinly bedded and laminated siltstone and arenite, massive blue-grey and pink fine grained arenite, and minor conglomerate. Some of the siltstone is calcareous, and at one locality contains pyrite euhedra and veins and clots of magnetite-calcite. These display replacement textures and may represent a skarn. Most of the wedge of metasediments east of the river probably forms part of the Espanola Formation, and the conglomerate probably belongs to the underlying Bruce Formation. However, the exact relationships are difficult to ascertain because of the presence of strike faults parallel to the Spanish River which have introduced narrow wedges of granite into the sedimentary sequence and which have been exploited by Sudbury Breccias. No outcrops were observed which can be confidently assigned to the Serpent Formation, but there is a paucity of exposure between outcrops of the Espanola and Gowganda Formations in this area possibly indicating the presence of unexposed Serpent Formation. Furthermore, previous workers (Card and Innes 1981) noted that the distinction between rocks of the Serpent and Gowganda Formations to the north of the present map area was uncertain. Therefore, some outcrops assigned to the Gowganda Formation may in fact belong to the Serpent Formation. A single outcrop of paraconglomerate of the Gowganda Formation is located near the eastern boundary of Tofflemire Township. This is the southwest extension of a metasedimentary outlier mapped in Hart Township by Choudhry (1984).

Approximately 2 km east of the central part of Fox Lake, a single outcrop some 75 m long and up to 20 m wide displays a sequence of vertically dipping interbedded polymictic para- and orthoconglomerate, arenite, and minor black argillite striking at 024°. The sequence faces east. The contact with the underlying granite a few metres away is not exposed, and so it is not possible to determine if the sediments have a structural or sedimentary contact with the granite.

This isolated outcrop most likely represents a part of the Bruce or Gowganda Formation.

In Vernon Township, about 2 km south of Titmouse Lake, an area approximately 800 by 400 m contains numerous small outcrops of massive grey siltstone, thinly bedded calcareous green and white siltstone, and buff coloured, fine to medium grained arenite. One outcrop contains alternating beds some 30 cm thick of laminated siltstone and recrystallized limestone containing fine acicular needles tentatively identified as tremolite. These outcrops constitute part of the Espanola Formation. Structural measurements indicate that this outlier describes the northwestern limb and part of the axial zone of a southwesterly plunging syncline. Severely sheared and quartz-veined granite occurs along the southwestern edge of the metasedimentary outlier suggesting that it is a downfaulted block, possibly an extension of the Vernon Syncline mapped by Card (1978). At one location, a faulted contact was observed between siltstone of the Espanola Formation and granite.

Near the southern boundary of the map area two outcrops of arkose and conglomerate of the Matinenda Formation represent the northern tip of the Vernon Syncline.

Lamprophyre

Numerous small lamprophyre dikes have been observed in the northern part of the project area. They are generally <1 m wide, have irregular contacts with the enclosing host rock, and can rarely be traced for more than a few metres. Most are mauve coloured, medium grained, calcareous, magnetic, and contain flakes of biotite up to 1 cm in diameter. Most occur within about 3 km of the Spanish River Carbonatite Complex. Clasts of lamprophyre occur in some Sudbury Breccias, and at one location a block of lamprophyre appeared to be included within Nipissing Diabase. This evidence indicates that at least some lamprophyre pre-dates the Sudbury event (1840 Ma) and the Nipissing Diabase (2160 Ma). It is thus considerably older than the 1415 Ma age reported for lamprophyre dikes in the Blind River area (Van Schmus 1971).

Nipissing Diabase

Nipissing Diabase dikes and sills are widely distributed throughout the map area and form bodies ranging from a few metres to several hundred metres wide. They are known to intrude Huronian rocks in other areas but here were observed intruding only granitic rocks. Rubidium-strontium whole rock radiometric ages have been determined as 2160 + 50 Ma (Fairbairn *et al.* 1969). The larger diabase bodies are outlined on Figure 2. Widely distributed outcrops of diabase in Vernon Township may represent parts of relatively large bodies but correlation is hampered by extensive overburden in this area. The Nipissing Diabase varies from fine to coarse grained and is dark grey on fresh surfaces, appearing less altered than the Archean dikes. It is usually only weakly or nonmagnetic and occasionally contains pyrite. The dikes commonly strike northwest or northeast.

Sudbury Breccia

Sudbury Breccias are pseudotachylites which have been observed up to 80 km away from the Sudbury Structure, and are believed to have formed by brittle fracture and comminution of footwall rocks in the explosive event which gave rise to the Sudbury Structure, and by later readjustments of the earth's crust. This event occurred approximately 1840 Ma ago (Krogh and Davis 1974). Sudbury Breccia bodies ranging in size from a few millimetres to several tens of metres are widely distributed through the map area. Their orientation is random and their outlines irregular. However, they are commonly exposed along cliff faces oriented at 030° and 130°, the two dominant fault and joint directions. The breccias have been observed cutting granite, Archean diabase, and metasediments of the Gowganda and Espanola Formations. Most breccias consist of an aphanitic, siliceous, medium grey coloured matrix containing rounded clasts of granite ranging in size from <1 cm up to 4 m. The larger bodies tend to have a higher clast to matrix ratio. Clasts of Archean and Nipissing diabase are widespread but not abundant. Clasts of lamprophyre, carbonate rock, and fenitized granite occur in northern Venturi Township near the Spanish River Carbonatite Complex, while in eastern Tofflemire Township and breccias contain clasts of conglomerate, sandstone, and siltstone derived from the local Huronian succession. The breccia matrix is commonly flow banded in the map area and amygdules have been noted at several localities. The matrix may also be massive. Near the Spanish River Carbonatite Complex, the matrix is calcareous and assumes a blue or green colour; and some bodies have been sheared. In some localities, two phases of brecciation are indicated by the presence of clasts of Sudbury Breccia within a younger matrix.

Spanish River Carbonatite Complex

The Spanish River Carbonatite Complex is located between "The Elbow" on Spanish River and Fox Lake. Its extent is not accurately known but appears to be about 1400 m in a north-northeast direction and 800 m across. It is exposed in only one outcrop where coarse-grained, banded and massive carbonate rock is visible. This contains scattered books of biotite up to 1 cm in diameter and pyroxene with trace pyrite. A biotite-quartz-carbonate rock containing pyrite and pyrrhotite also occurs at this locality. Exploratory pits excavated by earlier workers have caved in. Sage (1983) has described the complex in detail, including the results of a petrographic study of a deep diamond-drill hole completed by Union Carbide Canada Limited in 1968 (Proudfoot 1971). The complex contains silicocarbonatite, soevite, ijolite, pyroxenite, and cancrinite-nepheline syenite. Intrusion of the carbonatite was accompanied by fenitization of the surrounding granitic rocks for distances of up to 2 km from the margin of the complex. Within this alteration aureole, the quartz in the granite is progressively replaced by fibrous or acicular alkalic amphiboles and pyroxenes as the carbonatite is approached, and dikes of magnetite-bearing calcareous biotitic lamprophyre, calcite, and calcite ± magnetite ± biotite ± pyrite dikes are common. The granite is weakly carbonatized and commonly sheared or cataclastically deformed. Beyond the limit of visible fenitization, quartz-magnetite veins have been observed to the northwest and southeast of the complex striking approximately 040°. Small dikes of carbonate rock containing fibrous amphibole or biotite, of similar appearance to those described above, have been found as far as 10 km south and 6 km north of the complex. The complex has been dated by rubidium-strontium isotopic techniques as 1838 + 95 Ma. Its emplacement may, therefore, have been penecontemporaneous with the formation of the Sudbury Structure. However, as stated above, clasts of carbonate rocks, fenitized rocks, and lamprophyre occur in Sudbury Breccia believed to be associated with the Sudbury event and inclusions of lamprophyre possibly associated with the carbonatite were observed in Nipissing Diabase.

MIDDLE PROTEROZOIC

Olivine Diabase

Scattered outcrops of olivine diabase were encountered throughout the project area. They weather easily and consequently are poorly exposed, commonly occupying topographic depressions. In such situations, the dark green chilled margin often remains as isolated slabs adhering to the faces of granitic country rocks while the coarser grained core of the dike is recessive in northwesterly trending gullies. The rock commonly has a red-brown spheroidal weathered surface. The diabase is usually medium to coarse grained, with subophitic textures, and is magnetic; several outcrops correspond to linear aeromagnetic anomalies (ODM-GSC 1965). A well-developed joint set commonly parallels the trend of individual dikes. Similar dikes described by Card and Innes (1981) are thought to be approximately 1250 Ma old.

METAMORPHISM, ALTERATION, AND STRUCTURE

Low rank metamorphism associated with the Penokean Orogeny at about 1900 Ma ago (Van Schmus 1976) has affected the granites, Huronian metasediments, Nipissing and earlier diabase in the project area. The metamorphic grade is low to middle greenschist facies. Huronian metasediments in Tofflemire Township contain muscovite, pyrophyllite, and andalusite. Chlorite occurs on many joints and partings in granite throughout the area. In Vernon Township, recrystallized limestone of the Espanola Formation may indicate local thermal metamorphism possibly caused by Nipissing Diabase, several outcrops of which occur in the area. A similar relationship may occur in eastern Tofflemire Township where a possible magnetite-bearing skarn has been located (*see* above).

Fenitization of granite and diabase dikes surrounding the Spanish River Carbonatite Complex has been described above.

Most outcrops in the area are linear and are controlled by faults trending at 130° and 030°. Many joints strike parallel to these directions but the overall pattern of joint orientation is random. Locally, the granitic rocks display a nonpenetrative cataclastic foliation accompanied by quartz and/or chlorite veining. The relationship of these zones to major structures such as the north-northeast trending graben discussed above is not clear at the present time.

ECONOMIC GEOLOGY

To date, no mineral occurrences of economic significance have been located in the map area, and the only exploration work reported has focused on the Spanish River Carbonatite Complex. However, three geological environments exist in the map area which have mineralized counterparts elsewhere and should be considered for exploration work.

1. The Spanish River Carbonatite Complex. As discussed above, the complex has been tested by pitting and by five diamond-drill holes. Minor vermiculite, apatite, and pyrochlore have been identified. Core has been analyzed for copper, cobalt, nickel, vanadium, columbium, and platinoids but no significant results have been obtained. However, much of the complex remains untested and additional drilling may be warranted.
2. In Hart Township (east of Tofflemire Township), replacement type skarn deposits containing zinc, copper, lead, and cobalt occur in the Espanola Formation. The skarnification is believed to have been produced by heat generated by intrusion of Nipissing Diabase (W. Meyer, Resident Geologist, Ontario Ministry of Northern Affairs and Mines, Sudbury, personal communication, 1985). Although the area underlain by rocks of the Espanola Formation in the current map area is rather limited, some prospecting for similar mineralization is warranted. In Vernon Township, minor chalcopyrite was discovered in a calcite vein within a shear zone, accompanied by talc and quartz veining. The shear zone strikes at 080° and lies close to the (faulted?) contact of the Espanola Formation with granitic rocks. Several diabase dikes occur in the vicinity. 150 m farther east there is an outcrop of recrystallized limestone containing acicular crystals of tremolite, indicating local thermal metamorphism and raising the possibility of skarn-type mineralization. The outcrops of Espanola Formation in Tofflemire Township are of more restricted extent than those in Vernon Township. They lie in a structurally disturbed zone, and contain disseminated pyrite, veins and blebs of magnetite and calcite, and pseudomorphs of (?) scapolite. These features suggest that thermal metamorphism has occurred locally and so the area may warrant prospecting for skarn-type base metal mineralization.
3. Sedimentary Gold Mineralization. Over the years, many workers have pointed out similarities between the Huronian Supergroup and the Witwatersrand Basin in South Africa. Recently, anomalous values of gold have been obtained from hematitic quartz pebble conglomerates of the Lorrain Formation and from fluviatile units of some of the underlying formations (Long and Colvine 1984). The newly mapped areas of Lorrain and Gowganda Formations in Tofflemire Township, whilst of limited extent, may warrant

investigation as part of a regional exploration program directed towards the occurrence of sedimentary gold in Huronian strata.

In the course of mapping, one additional mineral occurrence was noted. A 1 metre wide shear zone cutting granite was found 400 m east of Fox Lake, due south of Fox Lake Lodge. The shear consisted of calcareous quartzose material containing disseminated pyrite, pyrrhotite, galena, magnetite, and siderite. The shear is also exploited by a small lamprophyre dike. There is very limited outcrop in the area. While the occurrence is far too small to be of economic interest, it is possible that the shear indicates a downfaulted fragment of material from the Espanola Formation, and therefore may indicate the presence of drift-covered rocks of the Espanola Formation nearby.

Extensive sand and gravel deposits occur along the Spanish River in eastern Tofflemire Township, through Fox Lake, and southward into east-central Vernon Township.

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20. Footwall Breccia and Breccias of the Onaping Formation in Levack and Morgan Townships, District of Sudbury

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INTRODUCTION

The area of investigation is located in Dowling, Levack, and Morgan Townships, north and south of the Sudbury Igneous Complex, and is part of an area previously mapped by Lafleur and Dressler (1985) and Muir (1983). Access to the area is via Highway 144 from Sudbury, a regional road to Levack, and many mining roads.

The 1985 investigations were carried out under a volunteer agreement between the Precambrian Geology Section of the Ontario Geological Survey and the Research Group "Earth-Moon-System", University of Muenster, Federal Republic of Germany. They represent a second year of scientific cooperation between the Ontario Geological Survey and the German research group, and are in partial fulfilment of the requirements for the Ph.D degree at the Geologisch-Palaeontologisches Institut, University of Muenster.

MINERAL EXPLORATION

Several nickel-copper deposits occur in the study area, which is one of the most productive regions of the Sudbury Mining Camp. It is beyond the scope of this summary report to describe the mining and exploration activities carried out in the area of investigation. The reader is referred to Pye *et al.* (1984) and Lafleur and Dressler (1985), for detailed accounts of the economic geology of the area.

FIELD INVESTIGATIONS

During the summer months of 1985, the authors placed emphasis on the following investigations:

(1) Study of the Footwall Breccia and the Basal Member of the Onaping Formation, and a comparison of these two geological units with each other.

One of the authors (R.L.) mapped in detail the occurrences of Footwall Breccia well exposed in an area extending from the Fecunis Lake Fault (Lafleur and Dressler 1985) to approximately the eastern boundary of Levack Township. The breccia in several aspects is similar to the breccias of the Basal Member of the Onaping Formation, separated from the Footwall Breccia by the intrusion of the Sudbury Igneous Complex. Several differences have been observed and noted also by previous workers (W.V. Peredery, Inco Limited, personal communication, 1985). For example, there is a scarcity of fragments of mafic and ultramafic rocks in the Basal Member, and an absence of fragments of meta-arenites of the Huronian Supergroup in the Footwall Breccia. Mafic and ultramafic fragments are common in the Footwall Breccia; fragments of meta-arenites are common in the Basal Member. Both breccias are considered to have originally belonged to one breccia accumulation subsequently split apart by the Sudbury Igneous Complex. The lithological differences may be explained by assuming an original breccia deposit grading from Footwall Breccia, containing mainly locally derived rock fragments, into the breccias of the Basal Member, containing fragments transported from more distant sources during the Sudbury Event (meteorite impact or endogenic explosion). Bulk assimilation by a gabbroic parental magma of the Sudbury Igneous Complex may be responsible for the disappearance of much of the transitional Footwall Breccia-Basal Member material, and may also be responsible for the origin of the granophyre of the Igneous Complex.

A large number of samples was taken from both breccia types for petrological and geochemical investigations.

(2) The second author (P.B.) of this summary report investigated, in detail, exposures of breccias of the Gray and Black Members and of Melt Bodies of the Onaping Formation.

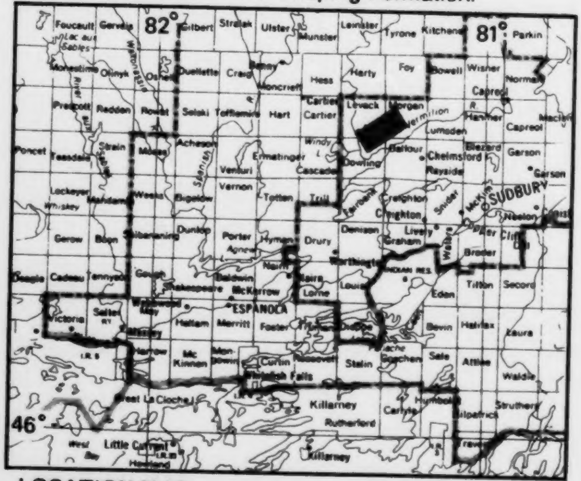
During the investigations, many of the observations made by previous workers (e.g. Muir and Peredery 1984) could be substantiated, including the recognition of multiple brecciation and of discontinuous, sharp contacts within the breccia deposit.

A large number of specimens were taken for petrological and geochemical studies. The following studies are planned:

(1) Microprobe analyses of various types of recrystallized glass fragments described by Muir and Peredery (1984).

(2) Study of shock metamorphic features in mineral and rock fragments.

(3) Geochemistry of breccia matrices of samples taken from a complete section across the upper two members of the Onaping Formation.



LOCATION MAP

Scale : 1 : 1 548 000
or 1 inch to 25 miles

(4) Statistical investigations of the breccias from a section across the Gray and Black Members. The statistics will deal with the abundances of the various rock and recrystallized glass fragments and their shapes and sizes.

Both authors hope to make contributions that will eventually lead to a better understanding of the origin of the Sudbury Structure. They gratefully acknowledge the assistance obtained during the field investigations from the management and geological staff of Falconbridge Limited and Inco Limited.

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21. Synoptic Mapping of the Kirkland Lake-Larder Lake Areas, District of Timiskaming

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INTRODUCTION

The Kirkland Lake-Larder Lake areas cover 2000 km^2 bounded by Latitudes 48°00′N and 48°15′N, and Longitudes 79°30′W and 80°30′W (Location Map). They contain the gold mining communities of Kirkland Lake and Virginiatown.

Synoptic mapping of the Kirkland Lake and Larder Lake areas is a multi-year program to remap a 24 township area in the Archean Abitibi Subprovince. The aim of the project is to delineate the volcanic rocks as to their respective komatiitic, tholeiitic, calc-alkalic, and alkalic volcanic suites, as well as to map their associated sedimentary and intrusive rocks. The stratigraphy and structure and zones of metamorphism and alteration revealed by the mapping provides important clues on the presently known zones of gold mineralization and will provide information to aid in locating additional mineralization in the Kirkland Lake-Larder Lake areas.

The past field season focused on the geology between the Round Lake Batholith and the Kirkland Lake-Larder Lake Fault Zone situated in the southern half of the Larder Lake map area. Mapping covered the northern edge of the Round Lake Batholith, the Pacaud Tuffs, and the Wabewawa, Catherine, Skead, and Larder Lake Groups, and the contact between the Larder Lake Group and the Timiskaming Group along the Kirkland Lake-Larder Lake Fault Zone (Table 1).

MINERAL EXPLORATION

Since the discovery of gold in the early 1910s, gold mining has remained one of the prime industries of the area. During the first half of the century, there were several mines operating but many operations closed down between 1950 and 1970. Only the Kerr Addison Mine in Virginiatown and the Macassa Mine in Kirkland Lake have remained in operation to the present.

From the 1950s to the 1970s, mineral exploration focused on the search for base metals, iron ore, asbestos, and diamonds. This exploration resulted in the opening of the Adams Mine (iron) in Boston Township, 5 km south of Kirkland Lake, which is still in operation under the management of DOFASCO Incorporated.

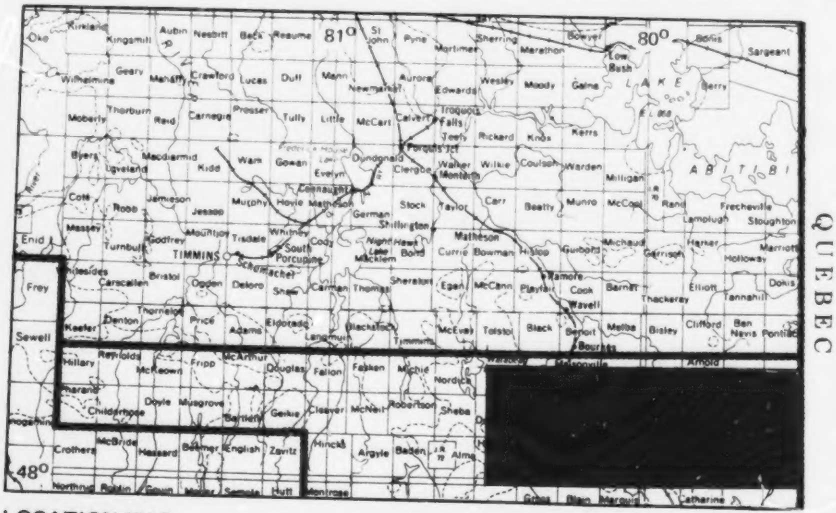
Gold exploration began to intensify in the late 1970s with the marked increase in gold prices and has continued strong until the present. This activity has resulted in the opening of the open pit McBean Mine operated by INCO Limited in Gauthier Township, the sinking of a second shaft at the Macassa Mine by the Macassa Division of Lac Minerals Limited, and the rejuvenation of the Lakeshore Mine by Lac Minerals Limited in Teck Township.

Simultaneous to this development, many of the past producing mines have undergone further reevaluation and many blocks of claims are being intensely explored by geological mapping, geophysics, surface stripping, and diamond drilling.

GENERAL GEOLOGY

Previous mapping by the author (Jensen 1980) has revealed that the Kirkland Lake-Larder Lake areas occupy the southern limb of a large east-plunging synclinorium (Figure 1). Three cycles of volcanism are contained in the southern limb of the synclinorium. The oldest cycle contains only the upper calc-alkalic Pacaud Tuffs intruded at their base by the trondhjemitic Round Lake Batholith.

The overlying second cycle consists of the komatiitic Wabewawa Group, tholeiitic Catherine



LOCATION MAP

Scale: 1: 1 584 000 or 1 inch to 25 miles

TABLE 1. SOUTHERN LIMB STRATIGRAPHY (PROJECT 21)

Group	Volcanic Rocks	Associated Sediments	Associated Intrusive Rocks	Relationships
Pacaud Tuffs	Calc-alkalic andesite, dacite, and rhyolite tuffs	Cherts and iron formation		Truncated by the Round Lake Batholite
Skead Group (SG)	Calc-alkalic basalt andesite, dacite, and rhyolite flows and pyroclastic rocks	Cherts and iron formation	Rhyolite porphyries	Conformably overlies CG
Catharine Group (CG)	Mg-rich and Fe-rich tholeiitic basalt	Minor argillite	Gabbro	Conformably overlies WG
Wabewawa Group (WG)	Peridotitic and basaltic komatiite and Mg-rich tholeiitic basalt. Minor rhyolite tuff	?	Dunite, peridotite, pyroxenite and gabbro	Overlies calcalkalic tuffs (Pacaud tuffs)
Timiskaming Group (Kirkland Lake-Larder Lake Section) 3000 m	Na- and K-rich mafic to felsic alkalic volcanic rocks and K-rich subalkalic felsic volcanic rocks	Fluviatile conglomerate, wacke, and argillite of material derived locally and from LLG	Mafic to felsic syenodiorite syenite, monzonite, granodiorite, and lamprophyre	Unconformably overlies BRG, KG, and in places LLG. Mainly a fault contact with LLG
Blake River Group (BRG) 10 000 m	Calc-alkalic basalt, andesite, dacite, and rhyolite flows, and pyroclastic rocks. Minor Mg-rich tholeiitic basalt	Volcaniclastic turbidites derived by slumping off volcanic edifices	Gabbro, diorite, quartz diorite, and rhyolite domes	Conformably overlies KG
Kinojevis Group (KG) 10 000 m	Mg-rich and Fe-rich tholeiitic basalt with minor tholeiitic andesite, dacite, and rhyolite flows	Hyaloclastite and argillite, chert, and graphite	Gabbro	Conformably overlies LLG
Larder Lake Group (LLG) Thickness unknown est. 5000 m	Peridotitic and basaltic komatiite and Mg-rich tholeiitic basalt, minor Fe basalt, calc-alkalic rhyolite tuff toward base of group	Turbiditic conglomerate wacke, argillite of material derived locally from komatiitic flows and distally from SG graphite, carbonate, and iron formation	Dunite, peridotite, pyroxenite, and gabbro	Disconformably overlies SG
		Pebble conglomerate with syenite clasts	Syenite intrusion?	

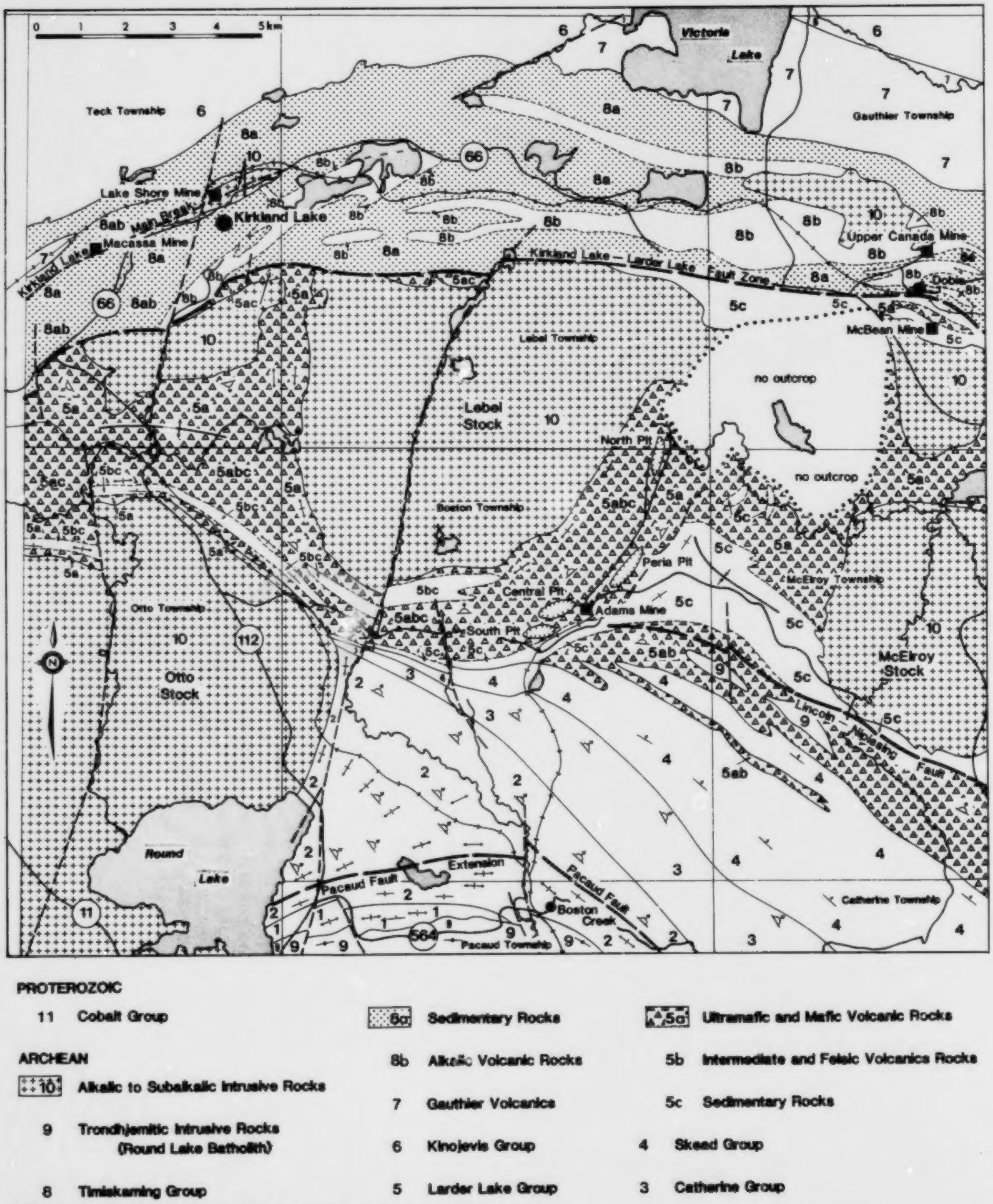
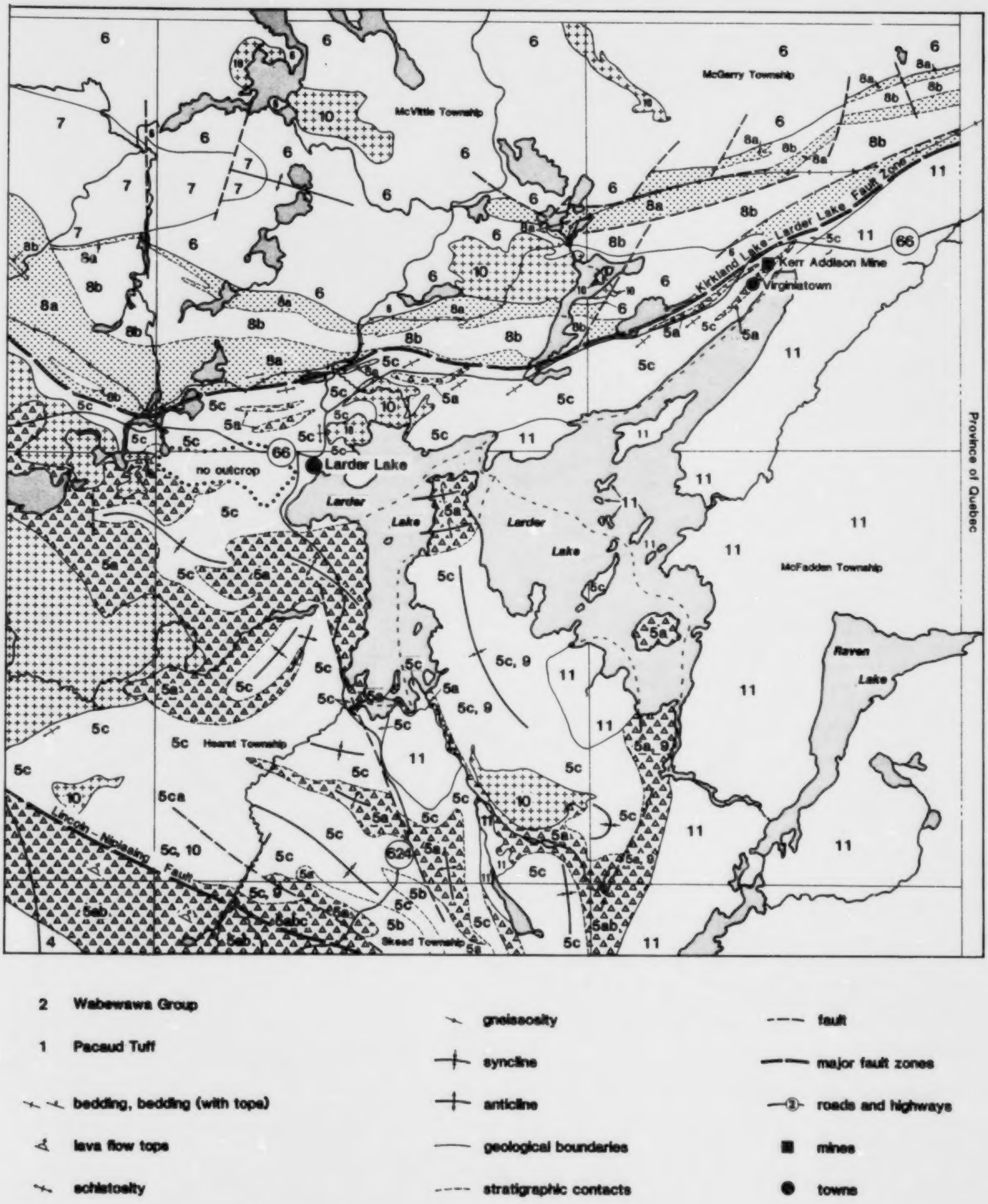
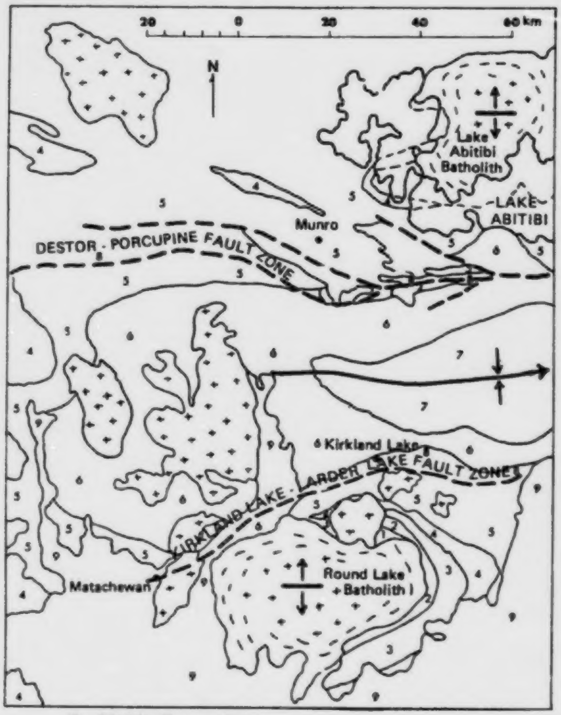

0 1 2 3 4 5km
Victoria Lake
Teck Township
Gauthier Township
Lake Shore Mine
Main Break
Kirkland Lake
Macassa Mine
Upper Canada Mine
Kirkland Lake – Larder Lake Fault Zone
Dobie
McBean Mine
Lebel Township
Lebel Stock
no outcrop
North Pit
Boston Township
Otto Township
Otto Stock
Central Pit
Peria Pit
Adams Mine
South Pit
McElroy Township
McElroy Stock
Lincoln – Nipissing Fault
Round Lake
Pacaud Fault
Extension
Boston Creek
Catherine Township
Pacaud Township
66
112
11
564
N
PROTEROZOIC
11 Cobalt Group
ARCHEAN
10 Alkalic to Subalkalic Intrusive Rocks
9 Trondhjemitic Intrusive Rocks (Round Lake Batholith)
8 Timiskaming Group
8a Sedimentary Rocks
8b Alkalic Volcanic Rocks
7 Gauthier Volcanics
6 Kinojevis Group
5 Larder Lake Group
5a Ultramafic and Mafic Volcanic Rocks
5b Intermediate and Felsic Volcanics Rocks
5c Sedimentary Rocks
4 Skead Group
3 Catherine Group

Figure 1. Stratigraphy of the Kirkland Lake area. (Project 21.)


McVittie Township
McGarry Township
Kirkland Lake - Larder Lake Fault Zone
Kerr Addison Mine
Virginiatown
Larder Lake
no outcrop
Larder Lake
Province of Quebec
McFadden Township
Raven Lake
Hearst Township
Lincoln - Nipissing Fault
Skead Township
66
624
2 Wabewawa Group
1 Pacaud Tuff
bedding, bedding (with tops)
lava flow tops
schistosity
gneissosity
syncline
anticline
geological boundaries
stratigraphic contacts
fault
major fault zones
roads and highways
mines
towns



9 Middle Precambrian
8 Timiskaming Group (alkalic)
7 Blake River Group (cala-alkalic)
6 Kinojevis Group (tholeiitic)
5 Stoughton - Roquemaure Group, Larder Lake Group and equivalents (komatiitic)
4 Hunter Miner Group, Skead Group and equivalents (calc-alkalic)
3 Catharine Group and equivalents (tholeiitic)
2 Wabewawa Group and equivalents (komatiitic)
1 Pacaud tuffs (calc-alkalic)

Figure 2. *Geology of the Kirkland Lake - Larder Lake area. (Project 21.)*

Group, and calc-alkalic Skead Group. The youngest third cycle consists of the komatiitic Larder Lake Group, tholeiitic Kinojevis Group, calc-alkalic Blake River Group, and alkalic Timiskaming Group. The Timiskaming Group is largely contained along the Kirkland Lake-Larder Lake Fault Zone where it unconformably overlies the Kinojevis and Blake River Groups on its northern side and is juxtaposed by faulting against the older Larder Lake Group on its southern side.

STRATIGRAPHY SOUTH OF KIRKLAND LAKE

Previous mapping in Boston and Pacaud Townships by Lawton (1959) suggested that the Pacaud Tuffs extended around the northern side of the Round Lake Batholith and that the overlying mafic volcanic rocks (Wabewawa Group) were conformable with the Pacaud Tuffs. Remapping north of the Round Lake Batholith reveals that the Pacaud Tuffs are limited to only a small wedge of calc-alkalic andesite tuff-breccias with units of fine ash and lapilli-tuffs of dacite and rhyolite composition (Figure 2). Massive flows of olivine normative magnesium-rich tholeiitic basalt are also present in the Pacaud Tuffs. The distribution of the calc-alkalic and tholeiitic units indicate the Pacaud Tuffs strike is easterly. The base of the Pacaud Tuffs is truncated by the Round Lake Batholith on the northern side of the batholith and the Pacaud Tuffs become completely cut off by the batholith toward the northeastern side of the batholith. The Pacaud Tuffs are <1000 m thick and are strongly schistose parallel to subparallel to their strike.

An abrupt change in lithology from rocks of calc-alkalic andesite and dacite composition to rocks of tholeiitic basalt composition occurs at the top of the Pacaud Tuffs. These overlying rocks, although highly schistose, appear to be predominantly wackes derived from a komatiitic-tholeiitic volcanic terrain. Units of iron formation and siliceous tuffs occur in the wackes along with massive to pillowed tholeiitic basalt units which suggest that the tholeiitic Wabewawa Group has a strike direction parallel to the Pacaud Tuffs and the two groups appear conformable.

A few hundred metres north, upward in the succession, where the schistosity becomes less intense, the strike of the Wabewawa Group changes to 330° nearly perpendicular to the Pacaud Tuffs. The abrupt change in strike and the observed penetrative deformation and drag folding suggests the presence of an deformation zone likely located in the lower part of the Wabewawa Group. This deformation zone likely represents a westward continuation of the Pacaud Fault (Lawton 1959) that occurs marginal to the Round Lake Batholith's northeastern side. Displacement along the deformation zone as well as the Pacaud Fault appears to be largely vertical and is in the order of several kilometres and indicates that the Wabewawa Group, although it appears conformable, was probably deposited unconformably to disconformably on the Pacaud Tuffs.

In the Wabewawa Group, komatiitic lavas are not readily apparent at the base of the group. They first appear as narrow talc-serpentine-chlorite schists north of the deformation zone and become a major component in the less deformed to undeformed upper part of the group. The komatiitic lavas appear to be sheared-out as they strike into the deformation zone as opposed to the more resistant tholeiitic lavas and wackes and tuffs.

The Wabewawa Group, as now preserved, has a maximum thickness of about 5 km north of the Round Lake Batholith. The flattening of the units towards its base and the angle between the deformation zone and the strike of the group suggests that the group was originally much thicker and was more extensive than the Catherine and Skead Groups higher in the second volcanic cycle above the Pacaud Tuffs. A thick differentiated pyroxene spinifex-bearing flow that can be traced for several kilometres marks the top of the Wabewawa Group.

The tholeiitic Catherine Group conformably overlies the Wabewawa Group. It consists of massive and pillowed lavas of magnesium- and iron-rich tholeiitic basalt. The two rock types alternate with one another as formations composed of several flows. Some thin sedimentary units consisting of siltstones, wackes, cherts, siliceous tuffs, and iron formation occur both between these formations and individual flows. Total thickness of the Catherine Group is about 7 km east of the Round Lake Batholith. Towards the northwest, the group thins to <2 km in the map area (Figure 2) before it is truncated by the Otto Syenite Stock, though it does reappear west of the stock (Jensen 1983).

The Skead Group above the Catherine Group represents an abrupt change from massive and pillowed tholeiitic basalt to calc-alkalic andesite and basalt tuff-breccias. Locally, the contact appears conformable but on a regional scale the contact is disconformable. Basal units of the Skead Group overlapped the upper units of Catherine Group (Figure 2). Upwards, the Skead Group consists of tuff-breccias alternating with finer, layered crystal tuffs, which range in composition from calc-alkalic andesite to rhyolite. In the tuff-breccia, the fragments are largely calc-alkalic andesite but in places pumice, granitoid (trondhjemitic), dioritic, and lithic fragments are also present.

The Skead Group has a 6 km thickness east of the Round Lake Batholith. To the northwest toward the Otto Syenite Stock, it thins to <200 m over a distance of 30 km. Only the basal units of the Skead Group are continuous for 30 km. As the upper units strike northwest, they interfinger with tholeiitic and komatiitic lavas of the Larder Lake Group such that it is only in the area east of the Round Lake Batholith that the Skead Group forms a continuous 6 km thick calc-alkalic volcanic succession. The fragmental units which interfinger with the komatiitic and tholeiitic lavas fine upward and westward into siliceous tuffs and cherts which in many places are strongly pyritic. In the western extremities of the Skead Group, the top of the Skead Group is marked by a matrix supported to clast supported conglomerate containing alkalic volcanic and intrusive pebbles of trachyte and syenite as well as chert, pyrite, and tholeiitic and komatiitic volcanic pebbles. The conglomerate mainly has a matrix of intermediate composition but locally it grades upward into a conglomerate with a pyritic cherty matrix, and in other places, a conglomerate composed solely of komatiitic volcanic detritus. This conglomerate probably represents a distal facies of the middle to upper parts of the Skead Group and it also suggests some alkalic volcanism and intrusion occurred near the end of the second volcanic cycle.

The contact between the Skead Group and the overlying Larder Lake Group is complicated by the fact that volcanism and sedimentation which produced the Larder Lake Group was already in progress laterally during deposition of the upper two thirds of the Skead Group's thickest parts. The two groups interfingered with the Larder Lake Group progressively onlapping the Skead Group upward in the succession (Figure 2). Consequently, all calc-alkalic volcanic units interfingering laterally contiguously from the Skead Group's thickest part into tholeiitic and komatiitic lavas of the Larder Lake Group are considered part of the Skead Group, while those calc-alkalic volcanic units isolated from the Skead Group by komatiitic and tholeiitic lavas are considered to be part of the Larder Lake Group.

The Larder Lake Group comprises a diverse suite of volcanic and sedimentary rocks that were deposited on an unstable shelf marginal to the volcanic pile formed by the Skead Group. The Larder Lake Group occupies the area from the Skead Group north to its contact with the Timiskaming Group along the Kirkland Lake-Larder Lake Fault Zone (Figure 2). Although the Larder Lake Group is locally strongly folded, faulted, and in places, intruded by granitoid rocks, facies changes in the volcanic and sedimentary rocks can be recognized.

In the Larder Lake Group, the main volcanic rocks are komatiitic and tholeiitic lavas. The subordinate volcanic rocks are mainly calc-alkalic well-bedded dacite and rhyolite tuff-breccias and tuffs. Some calc-alkalic basalt and andesite tuff-breccias are also present. The komatiitic lavas appear to be locally derived from numerous stocks and sills of peridotite found cutting the Larder Lake Group and the calc-alkalic rocks by explosive volcanism of distal, still active, volcanic centres that produced the main Skead Group. The highest proportion of calc-alkalic volcanic rock occurs near the base of the Larder Lake Group.

Sedimentary rocks form 40% to 50% of the Larder Lake Group. They consist of turbiditic clastic and chemical sedimentary rocks. They occur interlayered with the volcanic rocks. The clastic sedimentary rocks are conglomerates, wackes, siltstones, and mudstones derived from the erosion of rocks of various lithologies. The most abundant are those composed of detritus derived directly from the mechanical degradation of komatiitic and tholeiitic lavas. Many also have a clastic component ranging from boulder-size to sand-size material derived from the erosion of calc-alkalic dacite and rhyolite tuffs and tuff-breccias. An additional component to the clastic sedimentary rocks is redeposited detritus and clasts from the clastic and chemical sedimentary rocks themselves, particularly chert and banded iron formation. The komatiitic, tholeiitic, rhyolitic, and sedimentary components can vary greatly in proportion to each other throughout the sedimentary rocks of the Larder Lake Group.

Thin units of chert, banded iron formation, limestone, and carbonaceous material are the dominant chemical sedimentary rocks throughout the Larder Lake Group. These rocks can vary in abundance and thickness in different parts of the Larder Lake Group. In Boston Township, the iron formation is mined by open pit (Jensen 1978). Ore is extracted from iron formation from at least three stratigraphic levels having distinctive footwall, hanging wall, and intervening lithologies. The host rocks include weakly to undeformed spinifex-textured peridotitic komatiites and pillowed to massive tholeiitic basalts, calc-alkalic tuffs and tuff-breccias of andesite to rhyolite composition, and conglomerates composed largely of komatiitic detritus. Layers of massive talc-serpentine-chlorite-rich sediments and zones of iron-poor pyritic to nonpyritic, carbonaceous to noncarbonaceous cherts and cherty ash and crystal tuff are present within the zones of iron formation. These rocks, along with late lamprophyre, mafic to felsic alkalic, and diabase dikes form the waste rock in the open pit operations. The complex folding patterns in the banded iron formation and cherts are not reflected in the more competent host rocks and are probably the result of syndepositional folding accentuated by burial during lithification. The heat of emplacement of the nearby Lebel syenite stock and associated dikes has resulted in contact metamorphism of the iron formation to upper greenschist and amphibolite facies rank (Figure 2).

Bedded limestone units >1 m thick of pure $CaCO_3$ are rare in the Larder Lake Group. However, thick units of conglomerate having uncarbonatized clasts of peridotitic komatiite set in a matrix of fine grained $CaCO_3$ interlayered with thin beds of fine grained $CaCO_3$ are wide spread in the Larder Lake Group.

Graphitic and carbonaceous mudstones and cherts are common in the Larder Lake Group. They occur as thin interflow units between the komatiitic and tholeiitic lavas and as thick shaly units in the fine grained sedimentary rocks particularly in the northern parts of McElroy and Hearst Townships and the south parts of Gauthier, McGarry, and McVittie Townships. Most of these units contain pyrite and can have some lead, zinc, copper, silver, and gold with the pyrite. Many of the carbonaceous rocks have or grade upward into bedded fuchsite-rich and carbonate-rich layers or have layers of chert associated with them.

In the Larder Lake Group, the sedimentary rocks tend to become more lithologically complex and form thicker sections toward their northern limit, particularly in the northern parts of McElroy and Hearst Townships and the southern parts of Gauthier, McGarry, and McVittie Townships. In this area, the clastic sedimentary rocks contain detritus eroded from the chemically altered and weathered volcanic and sedimentary rocks, presumably those formed earlier and farther south in the Larder Lake Group higher on the shelf. In the siltstones and mudstones, the talc-serpentine-chlorite-rich sedimentary units are interlayered with sericite-, chlorite-, silica-, dolomitic-, and fuchsite-rich units. Dolomitic and fuchsitic sandstones with varying amounts of detrital quartz are also found.

The associated conglomerates have all proportions of clasts varying in composition from serpentine-rich peridotitic komatiite through weakly carbonatized peridotitic komatiite to strongly carbonatized peridotitic komatiite and fuchsitic peridotitic komatiite mixed with other clast types such as rhyolite, chert, iron formation, and carbonate. Most of the fuchsite units (green carbonate rocks) in the Larder Lake Group are predominantly conglomerates. Some of the fuchsitic sedimentary rocks may be sedimentary rocks altered *in situ*, but most of the textural evidence suggests that these rocks were formed by the erosion of previously altered komatiitic lavas.

Fuchsitic and carbonatized komatiitic and tholeiitic lavas occur within the Larder Lake Group. They are interlayered with carbonaceous mudstones and carbonate-rich sediments. The fuchsitic rocks do not mark major structural breaks or fault zones as was implied by Thomson (1943, 1950), instead they appear to represent a sedimentary environment or a facies of sedimentation that was near the edge of a sedimentary shelf which also involved the early development of the Kirkland Lake-Larder Lake Fault Zone during the deposition of the Larder Lake Group.

The Timiskaming Group occurs on the northern side of the Kirkland Lake-Larder Lake Fault Zone. In the Larder Lake area, the Timiskaming Group is largely composed of fluvial, buff coloured sandstones, wackes, and conglomerates that in places resemble the Larder Lake Group. They can be recognized by their trachyte and jasper clasts and distinguished from the Larder Lake Group by the absence of abundant fuchsitic and komatiitic clasts.

Alkalic intrusions cut all of the volcanic rocks situated between the Round Lake Batholith north to the Timiskaming Group (Figure 2). The largest bodies are the Otto, Lebel, and McElroy Stocks. All three are comprised of several phases that include pyroxenite, hornblendite, biotite, alkalic gabbro and diorite, monzonite, syenite and granodiorite. These stocks have metamorphosed their surrounding host rocks to the amphibolite rank and have imposed on them a schistose fabric.

The remaining alkalic rocks are dikes and sills located throughout the areas between the major stocks. They include lamprophyre, feldspar porphyry and intrusions of similar composition to phases in the larger stocks. These intrusions have locally metasomatized, and, in a few places, carbonatized the country rocks and have caused quartz and quartz-carbonate veining without imposing a fabric on the host rocks. Some gold, molybdenum, and copper mineralization is associated with these intrusions.

Relative ages of the alkalic intrusions are difficult to determine. Pebbles of syenite occur in the conglomerate at the top of the Skead Group to suggest that some alkalic intrusions that cut the Skead and lower groups, are older than those cutting the Larder Lake and younger groups of rock. During the emplacement of the Otto, Lebel, and McElroy Stocks, a schistose fabric was imposed on some of the smaller alkalic intrusive bodies to suggest that alkalic rocks of more than one age cut the Larder Lake Group. The large zones of alteration, and fabric development around the Lebel Stock and similar stocks do not extend across the Kirkland Lake-Larder Lake Fault Zone to affect the Timiskaming Group. This suggests either that the Timiskaming Group and hence its crosscutting alkalic intrusive rocks are younger than the Lebel and other major stocks or that the displacement along the fault zone was sufficient to obscure the contact relationships. The major stocks and associated dikes are boudinaged along the Kirkland Lake-Larder Lake Fault Zone indicating that they were involved in some movement along the fault zone.

A few of the alkalic intrusions are carbonate bearing. These intrusions tend to be hosted by carbonate-rich sedimentary rocks in the Larder Lake Group which suggests that they incorporated and redistributed the carbonate from the host rocks. Elsewhere, the alkalic intrusions are carbonate poor.

STRUCTURAL GEOLOGY

The major fault zones are indicated by discontinuities in the lithology, variation in orientation and style of tectonic deformation of the bedrock. For example, the abrupt change in strike of the upper parts of the Wabewawa Group compared with its base and the underlying Pacaud Tuff suggests a major fault separates the Round Lake Batholith and its surrounding rocks from the younger rocks farther north (Figure 2). This fault may be the extension of the Pacaud Fault situated northeast of the batholith and first recognized by Lawton (1957). Much of the deformation associated with this fault appears to be taken up by the metasediments and komatiitic lavas near the base of the Wabewawa Group.

The Lincoln-Nipissing Shear Zone-Manor Fault system (Hewitt 1951) that extends from Skead Township into McElroy and Boston Township represents a second major discontinuity (Figure 2). In the area between the Pacaud Fault and the Lincoln-Nipissing Shear Zone and the Pacaud Fault, the Wabewawa, Catherine, and Skead Groups and basal part of the Larder Lake Group form a northeast-facing homoclinal succession up to 16 km thick. Farther to the north, the Larder Lake Group is folded into a series of synclines and anticlines with variable fold axes orientation (Thomson 1947). Much of the Larder Lake Group shows little or no penetrative deformation in spite of the folding within it. Penetrative deformation is largely restricted to the margins of the large alkalic stocks and to the Kirkland Lake-Larder Lake Fault Zone near Larder Lake.

Along most of the Kirkland Lake-Larder Lake Fault Zone, the deformation is restricted to a narrow schistose zone a few metres wide with little or no accompanying deformation in the Timiskaming Group. From Gauthier Township to McGarry Township, however, in the Larder Lake Group, the deformation zone widens, and rocks show two or more phases of deformation and, as well the southern edge of the Timiskaming Group has been deformed. The higher degree of deformation in these rocks is believed to be the result of the rocks being predominantly incompetent sedimentary rocks formed farther north on the shelf where syntectonic deformation was greater instead of being mainly tholeiitic and komatiitic lavas as found elsewhere. Only remanents of the sediments are preserved along the western part of the Kirkland Lake-Larder Lake Fault Zone (Figure 2).

ECONOMIC GEOLOGY

In the Kirkland Lake-Larder Lake areas, gold and iron ore are the only commodities presently produced. Field mapping this season suggests that the area south of Kirkland Lake is also favourable for copper, zinc, lead, molybdenum, nickel, and asbestos and has an even greater potential for gold and silver then is now presently known. Diamonds are also an exploration target as kimberlite is known to occur, both at the Upper Canada Mine (Lee 1968) and at the Adams Mine (K. Oliver, DOFASCO Incorporated, personal communication, 1978).

Gold mineralization in the area mainly occurs in the Larder Lake and Timiskaming Groups. The McBean open-pit and the Kerr Addison Mine, along with several past producers situated between these two ore deposits, are located in the sedimentary-rich parts of the Larder Lake Group near its northern edge (Figure 2). The gold mineralization closely follows the stratigraphy of the sedimentary rocks. Preliminary results from chemical analyses of the rocks by the author suggest that many of the cherty, carbonaceous, clayey (sericitic), carbonate and fuchsitic sedimentary rocks are enriched 10 to 100 times background (2 to 5 ppb) in their gold content, and, in places, reach ore grades as opposed to the talc-serpentine and chloritic sediments and banded iron formations. This suggests that gold-bearing sediments were deposited at the edge of a volcanic-sedimentary shelf and that they have acted as a primary gold source (Jensen 1981). In such an environment, the sediments would have become strongly deformed by syndepositional subsidence along the outer edge of the shelf during early development of the Kirkland Lake-Larder Lake Fault Zone. Secondary and tertiary concentration of the gold is likely to have occurred in volcanic rocks which incorporated sedimentary material, and in quartz-carbonate veins, syenitic intrusions, in fractures and alteration zones.

None of the gold mines, found to date, are located directly on the Kirkland Lake-Larder Lake Fault Zone. As well, the fuchsite-rich rocks do not correlate with major fault zones or alteration zones as has been suggested by Thomson (1943, 1950). Instead these rocks are mainly sedimentary strata within the Larder Lake Group, and, along with the other rock types in the Larder Lake Group, they are cut off by the Kirkland Lake Fault Zone. The sedimentary strata which host the gold-bearing rocks in the Larder Lake area appear to be largely truncated by the Kirkland Lake-Larder Lake Fault Zone farther west towards Kirkland Lake. On the northern side of the fault zone, the sedimentary rocks of the Larder Lake Group were downdropped and buried by younger rocks of the Timiskaming Group.

In the Timiskaming Group, the gold in the Kirkland Lake camp occurs in quartz-filled fractures and alteration zones associated with the Kirkland Lake 'break' and in the feldspar porphyries which cut the Timiskaming Group trachytes and sedimentary rocks. The relationship of the gold mineralization in the Larder Lake Group and the Timiskaming Group is unclear. It is probable that gold-bearing sediments of the Larder Lake Group were downfaulted on the northern side of the Kirkland Lake-Larder Lake Fault Zone below the Timiskaming Group and gold has been remobilized upward during alkalic intrusion and volcanism (Jensen 1981).

Where gold is associated with alkalic intrusive porphyries and granitoid rocks, the mineralization appears not to be controlled by the relative age of the intrusion but instead its location. In addition to the Kirkland Lake-Larder Lake Zone, a few of the alkalic intrusions in the vicinity of Boston Creek have gold mineralization in quartz-veins and quartz-carbonate veins. Elsewhere, the alkalic intrusive rocks seem to be barren of gold.

Gold in anomalous quantities (20 to 300 ppb) occurs in sulphide facies of iron formation at the base of the Wabewawa Group and pyritic tuffs of the Pacaud Tuffs and the Skead Group, as well as in some of the quartz veins associated with alkalic intrusive rocks. It is possible that the Pacaud Fault Zone is similar in origin to the Kirkland Lake-Larder Lake Fault Zone. As a result Wabewawa, Catherine, and Skead Groups subsided during their accumulation relative to the Pacaud Tuffs (Jensen 1985). Tuffs and sediments deposited more distally to the volcanic sources of the Pacaud Tuffs and more anomalous in gold than those now exposed, may have been buried with the result that a secondary enrichment occurred and gold was subsequently remobilized upward in the alkalic intrusions near Boston Creek.

Copper, zinc, and lead occur in the sulphide facies of the iron formations at the base of the Wabewawa Group near Boston Creek and in the Larder Lake Group farther north. Lesser concentrations of these metals occur as sulphide mineralization in the felsic calc-alkalic tuffs of the Pacaud Tuffs and the Skead Group.

Molybdenite occurs in some quartz veins associated with small alkalic granitoid stocks in Boston Township and asbestos occurs in places in the larger stocks and sills of peridotite in the Larder Lake Group.

RECOMMENDATIONS TO PROSPECTORS

Further exploration for gold mineralization should be carried out both east and west of Boston Creek to evaluate the Pacaud Fault Zone. Both the felsic tuffs and sediments as well as the alkalic intrusive rocks that cut these rocks and the volcanic rocks on the northern side of the fault should be examined.

Additional gold exploration should be undertaken on the fuchsitic, carbonate, sericitic, and carbonaceous sediments belonging to the Larder Lake Group west of the Lebel Stock. Some of these rocks are preserved parts of the sedimentary succession found in the vicinity of Larder Lake and others represent interflow sediments in the Larder Lake volcanic succession. As well, fractures, quartz veins, porphyries, and pyritic zones in the Timiskaming Group should be searched for and examined along the full length of the Timiskaming Group.

Pyritic tuffs and conglomerates near the contact between the Skead Group and the younger Larder Lake Group represent an additional target for gold mineralization.

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22. Lochlin Area, Haliburton County

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INTRODUCTION

The Lochlin area is located 140 km northeast of the City of Toronto and includes parts of Dysart, Glamorgan, Lutterworth, Minden, and Snowdon Townships. The Town of Minden lies near the west-central boundary of the map area, and access is provided by Highways 35 and 121, and Haliburton County Roads 1,16,17, and 18. Additional access is provided by township roads, an abandoned Canadian National Railway right-of-way, cottage roads, and snowmobile and ski trails. Extensive till cover is present in the western and northern parts of the map area, obscuring bedrock geology.

MINERAL EXPLORATION

The history of mineral exploration and production in the Lochlin area dates back to the 1880s, when massive magnetite ore (1000 tons) was extracted from the Imperial Mine situated along the Irondale, Bancroft and Ottawa railway. Marble was also extracted along this rail route in the vicinity of Maxwells at the turn of the century. A number of stone quarries were in operation in the past in the map area (Figure 1), operating mainly in the late 1930s and early 1940s, producing stone for use as concrete aggregate, road metal, and flagstone. No quarries are currently operating in the Lochlin area.

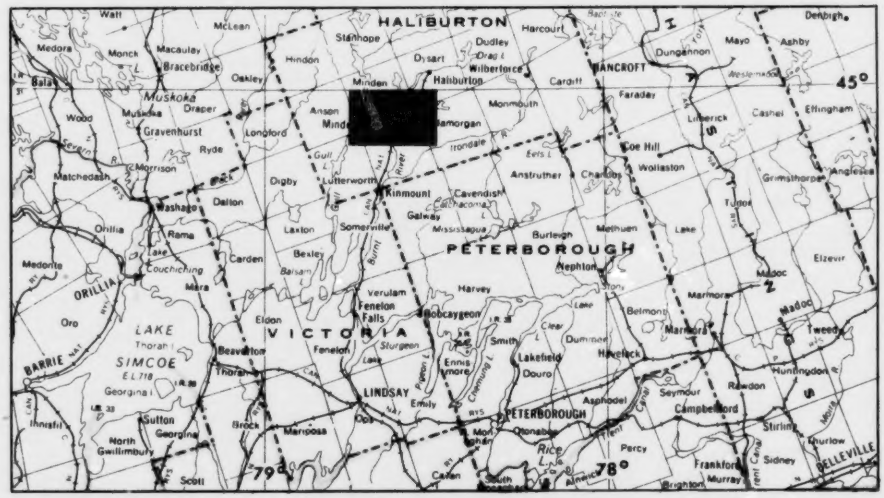
Recorded exploration within the map area has been limited (Assessment Files Research Office, Ontario Geological Survey, Toronto (AFRO)) despite considerable exploration work just east of the map area (Bright 1980). Uranium exploration occurred in the late 1960s, but only a few small showings were located (Figure 1). Geological Data Inventory Folios (GDIF) are now available for Glamorgan (Ontario Geological Survey 1983a) and Snowdon (Ontario Geological Survey 1983b) Townships. In addition, field party personnel located several pits in the area for which no information is on record in the Assessment Files Research Office (Figure 1).

GENERAL GEOLOGY

The Lochlin area is underlain by Precambrian rocks of Middle to Late Proterozoic age which form part of the Central Metasedimentary Belt of the Grenville Province. In addition, along the western boundary of the map area, are found deformed Middle to Late Proterozoic rocks of the Central Metasedimentary Belt Boundary Zone (CMBBZ) which separates supracrustal rocks of the Central Metasedimentary Belt from granitoid gneisses of the Central Gneiss Belt to the west.

Precambrian rocks of the area can be divided into five main groups (Figure 1). In order of interpreted decreasing age, these are:

1. The Glamorgan Gneiss Complex, which underlies the central and eastern part of the map area (Figure 1).
2. The Dysart Gneiss Complex, which may be roughly similar in age and origin to the Glamorgan Gneiss Complex, and which is only exposed in the north central part of the map area (Figure 1).
3. Grenville Supergroup rocks present in the extreme southeast corner of the map area (Figure 1).
4. The Denna Lake Structural Complex, which underlies the western third of the map area, and which consists of disrupted Grenville Supergroup strata, including marble tectonic breccia. In addition, a number of anorthosite bodies are present within the Denna Lake Structural Complex.
5. Highly deformed rocks of the Central Metasedimentary Belt Boundary Zone (CMBBZ) present west of Horseshoe Lake (Figure 1).



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

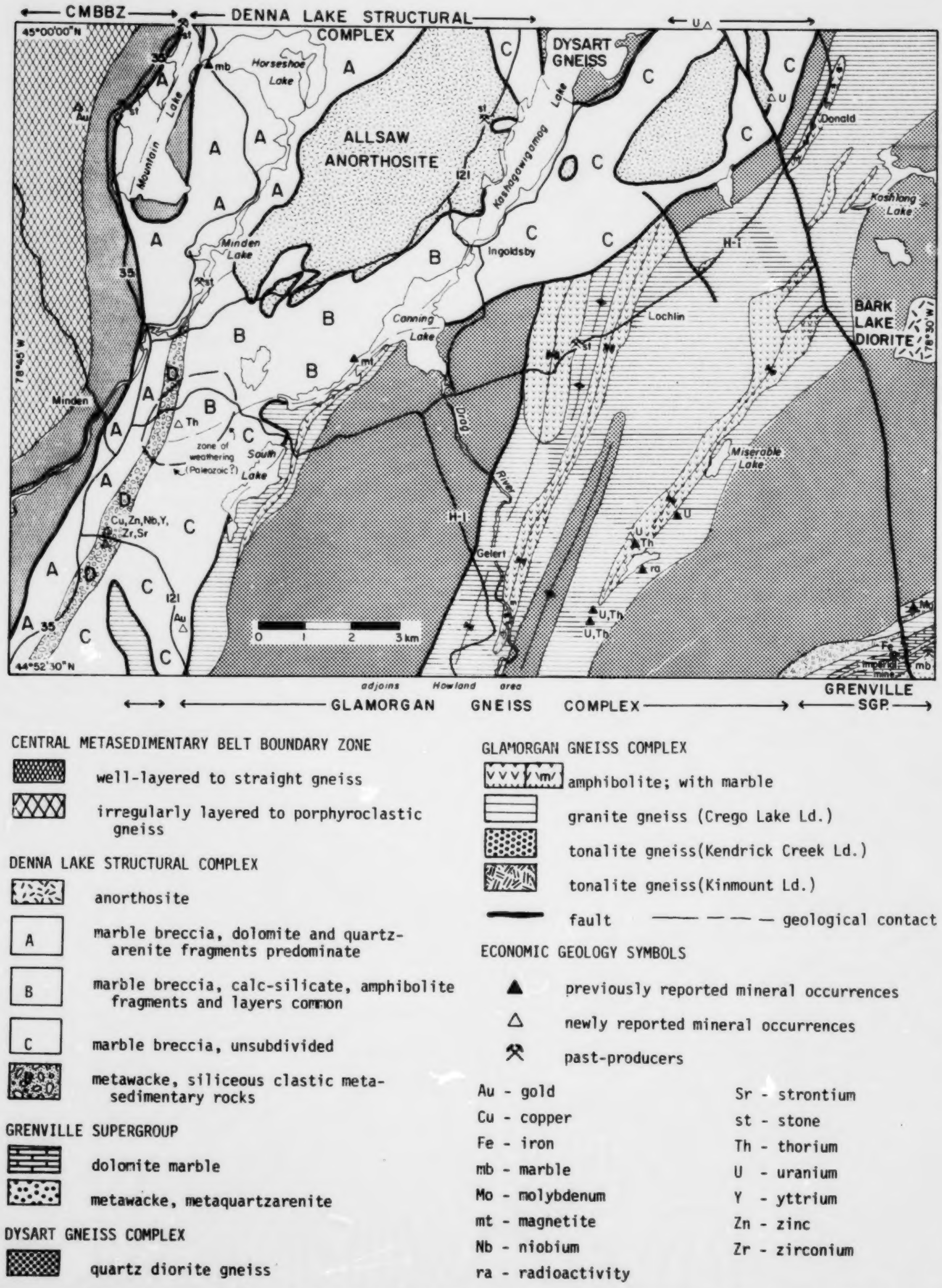

CMBBZ
DENNA LAKE STRUCTURAL COMPLEX
U △
DYSART GNEISS
ALLSAW ANORTHOSITE
BARK LAKE DIORITE
45°00'00"N
44°52'30"N
78°45'W
78°30'W
Horseshoe Lake
Mountain Lake
Minden Lake
Canning Lake
South Lake
Kashagawigamog Lake
Koshlong Lake
Miserable Lake
Drag River
Minden
Ingoldsby
Lochlin
Gelert
Donald
Imperial mine
zone of weathering (Paleozoic?)
Cu,Zn,Nb,Y,Zr,Sr
H-I
35
121
0 1 2 3 km
adjoins Howland area
GLAMORGAN GNEISS COMPLEX
GRENVILLE SGP.
CENTRAL METASEDIMENTARY BELT BOUNDARY ZONE
well-layered to straight gneiss
irregularly layered to porphyroclastic gneiss
DENNA LAKE STRUCTURAL COMPLEX
anorthosite
A marble breccia, dolomite and quartz-arenite fragments predominate
B marble breccia, calc-silicate, amphibolite fragments and layers common
C marble breccia, unsubdivided
metawacke, siliceous clastic metasedimentary rocks
GRENVILLE SUPERGROUP
dolomite marble
metawacke, metaquartzarenite
DYSART GNEISS COMPLEX
quartz diorite gneiss
GLAMORGAN GNEISS COMPLEX
amphibolite; with marble
granite gneiss (Crego Lake Ld.)
tonalite gneiss(Kendrick Creek Ld.)
tonalite gneiss(Kinmount Ld.)
fault
geological contact
ECONOMIC GEOLOGY SYMBOLS
previously reported mineral occurrences
newly reported mineral occurrences
past-producers
Au - gold
Cu - copper
Fe - iron
mb - marble
Mo - molybdenum
mt - magnetite
Nb - niobium
ra - radioactivity
Sr - strontium
st - stone
Th - thorium
U - uranium
Y - yttrium
Zn - zinc
Zr - zirconium

Figure 1. Map of the Lochlin area showing the location of mineral occurrences, major tectonic zones, and general geology. (Project 22.)

GLAMORGAN GNEISS COMPLEX

The Glamorgan Gneiss Complex in the adjacent Howland area to the south has been described in detail by Easton (1983) and Easton and Bartlett (1984), who subdivided the Complex into six lithodemic units. The three main lithodemic units present in both the Howland and the Lochlin areas are the Kinmount, Kendrick Creek, and Crego Lake Lithodemes (Figure 1). However, a number of lithologic, textural, and structural changes occur in the Complex between the Howland area and Koshlong Lake. First, the Glamorgan Gneiss Complex in the Lochlin area can be divided into two zones. The first zone, located in the region between South Lake and the Drag River, is most similar to the Glamorgan Complex in the Howland area. consisting mainly of tonalite gneiss of the Kendrick Creek Lithodeme, with minor amounts of amphibolite and granite gneiss of the Crego Lake Lithodeme present, along the contact with the Denna Lake Structural Complex. This zone also contains a number of exposures of mafic dikes which cut the Kendrick Creek Lithodeme, but were metamorphosed and deformed with the host rock.

The second zone extends east and northeast of the Drag River, and contains roughly equal proportions of granite gneiss (Crego Lake Lithodeme) and tonalite gneiss (Kendrick Creek Lithodeme), as well as several semi-continuous bands of amphibolite gneiss (Figure 1). Between the southern boundary of the map area and Koshlong Lake, rocks of the Kendrick Creek Lithodeme change in composition from tonalite to granodiorite in the northeast, outcrop scale and larger scale folding of gneissosity becomes more abundant, clots and pods of granodiorite leucosome develop in the tonalite gneiss, and an increasing number of sub-parallel to highly crosscutting granite veins are present. Rocks of the Crego Lake Lithodeme in the eastern zone of the Complex also change from the Howland area, tending away from syenogranite composition to quartz monzonite and monzogranite compositions near Koshlong Lake. The Crego Lake Lithodeme is intrusive into rocks of the Kendrick Creek Lithodeme.

The greater heterogeneity of the Glamorgan Gneiss Complex in the Lochlin area, relative to the Howland area, may reflect repeated folding, on a local scale, of rock present along the contact of the Kendrick Creek and Crego Lake Lithodeme. This folding is reflected in the semi-continuous bands of amphibolite, and locally marble, that occur in synformal axes within the Glamorgan Gneiss Complex in the Lochlin area (Figure 1). Figure 2 is a compilation map of the Glamorgan Complex based on this study, Bright (1980), Culshaw (1981), and Easton (1983) and shows increasing complexity, in part due to folding, within the Complex to the northeast. Late granite veins are also more common in the northeast part of the Complex. These changes may be due to exposure of a higher structural level of the Complex to the northeast, one which shows greater interaction between the Complex and its cover rocks. Folds in the synformal structures within the Glamorgan Complex in the Lochlin area (Figures 1,2) are clearly truncated by the northern contact of the Complex, and indicate folding of the Glamorgan Complex probably occurred prior to final thrust emplacement of the Complex (Easton 1983).

Southeast of Lochlin Lake, the Glamorgan Gneiss Complex is intruded by the Bark Lake diorite, a Middle Proterozoic intrusion that is part of a suite of diorite intrusions in the region which intrude both Grenville Supergroup rocks and the Glamorgan Complex.

DYSART GNEISS COMPLEX

The Dysart Gneiss Complex is exposed only along the shores of Kashagawigamog Lake in the north central part of the map area, and consists mainly of quartz diorite to tonalite gneiss. The Complex is more extensive to the north, where it has been described by Culshaw (1981). It is possible that the Dysart Gneiss Complex and the Glamorgan Gneiss Complex were at one time part of the same body, now disrupted by thrusting.

GRENVILLE SUPERGROUP

Grenville Supergroup metasediments outcrop in the extreme southeast corner of the map area, and consist of dolomite marbles, metaquartzarenites, and deformed metawackes. These rocks have been described in detail by Easton and Bartlett (1984) and Armstrong and Gittins (1968).

DENNA LAKE STRUCTURAL COMPLEX

The Denna Lake Structural Complex has been described by Easton (1983), Easton and Bartlett (1984), and Easton and Van Kranendonk (1984). It consists mainly of marble tectonic breccia, containing a variety of fragments, including amphibolite, calc-silicate gneiss, metaquartzarenite, other siliceous clastic metasediments, and disrupted granodioritic to granitic rocks. All lithologies present in the Denna Lake Complex have relatively undeformed counterparts 20 km to the east, on the southeastern margin of the Glamorgan Gneiss Complex. It is possible to subdivide the Denna Lake Complex into a number of zones on the basis of dominant clast lithology (Easton and Van Kranendonk 1984), and four zones are present in the Lochlin area, as shown in Figure 1. In addition, a number of sheets of anorthosite is present in the Denna Lake Structural Complex between Minden and Kashlong Lake (Figure 1). These bodies have relatively undeformed cores, and strongly deformed margins, and may be thrust slices, similar to the Glamorgan and Dysart Complexes.

CENTRAL METASEDIMENTARY BELT BOUNDARY ZONE (CMBBZ)

Rocks within this zone have been tectonically modified and have been described by Easton *et al.* (1984), and Hanmer and Ciesielski (1984). These rocks are poorly exposed in the Lochlin area because of extensive glaciofluvial deposits along the Gull River. Using the terminology of Hanmer and Ciesielski (1984), two main tectonites are present in this zone. In the east, tectonites consist mainly of straight gneisses, commonly of granitic composition. In the west, irregularly layered and porphyroclastic gneisses predominate. These rocks are exposed west

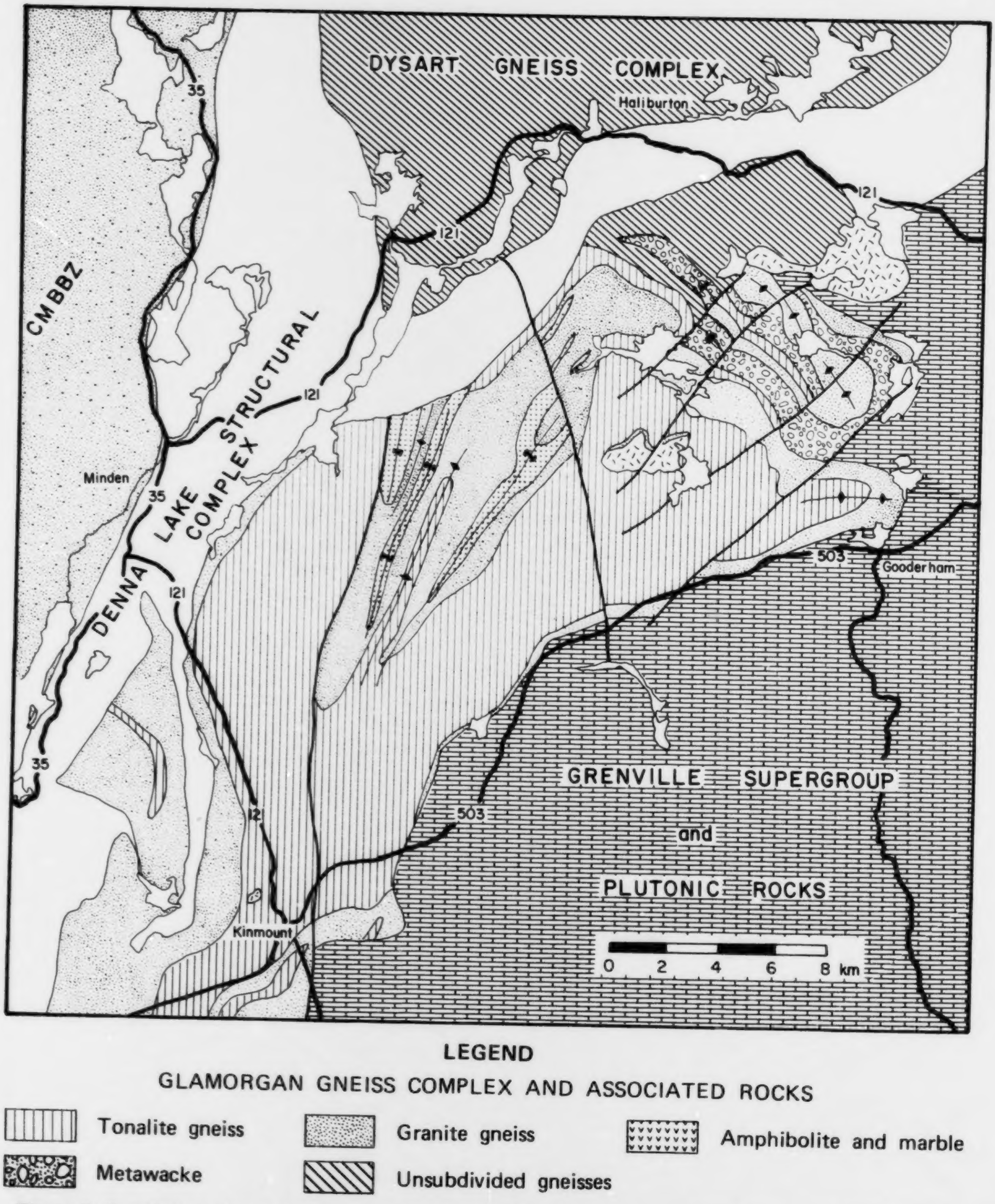

DYSART GNEISS COMPLEX
Haliburton
121
35
CMBBZ
DENNA LAKE STRUCTURAL COMPLEX
Minden
121
35
121
503
Gooderham
GRENVILLE SUPERGROUP and PLUTONIC ROCKS
503
121
Kinmount
0 2 4 6 8 km
LEGEND
GLAMORGAN GNEISS COMPLEX AND ASSOCIATED ROCKS
Tonalite gneiss
Granite gneiss
Amphibolite and marble
Metawacke
Unsubdivided gneisses

Figure 2. *Compilation map of the Glamorgan Gneiss Complex, based on maps by Easton and Bartlett (1984), Bright (1980), Culshaw (1981) and this study. Folding and greater interaction between basement and cover rocks occurs in the northeast part of the Complex. (Project 22.)*

of Highway 35, and in an erosional window cut through marble breccia of the Denna Lake Structural Complex on the shores of Mountain Lake (Figure 1).

METAMORPHISM AND STRUCTURAL GEOLOGY

Metamorphic grade across the map area is upper amphibolite facies. The structural geology of the area is dominated by the contacts, probably all faulted, between the major rock groups in the area. Large scale folding is only observed within the Glamorgan Gneiss Complex. All rocks in the Lochlin area contain a shallow-plunging, southeast-trending lineation. A major late fault extends from the southeast corner of the map area through Donald, displacing rocks within both the Glamorgan and the Denna Lake Complexes. Structures within the map area are consistent with a northwest-directed thrusting of the CMB over the CGB (e.g. Culshaw 1981; Hanmer and Ciesielski 1984).

ECONOMIC GEOLOGY

A number of occurrences of uranium and thorium mineralization have been located previously in the map area. All of these occurrences have significant scintillometer anomalies (up to 20 times background), lie within regional airborne gamma-ray spectrometric anomalies (Geological Survey of Canada 1984), and are areas of abundant pegmatite intrusion. In 1967 and 1968, Miro Mines Limited examined the area south of Miserable Lake and found three radioactive occurrences (Figure 1). Mineralization (relatively low grade) was localized in pegmatite veins in the area (AFRO). These occurrences are associated with amphibolite and Bright (1980) noted an association between mafic rocks and uranium occurrences in the Eel's Lake area. Consequently, gamma-ray anomalies in areas underlain by amphibolitic rocks make the most favourable exploration target for uranium and thorium mineralization in the map area. In addition, field party personnel located old pits, or high assay values for uranium or thorium on concession 3, lot 5 and concession 5, lot 3 of Dysart Township, and on lot 2, concession 1 of Minden Township (Figure 1).

Bill Kulas (prospector, Minden, personal communication, 1985) informed field party personnel of a gold occurrence in gneisses of the CMBBZ located on concession 8, lot 2 of Minden Township. An assay done in Oregon in 1904 reported 1 to 2 ounces gold per ton. Ten assay samples collected by field party personnel and assayed by the Geoscience Laboratories, Ontario Geological Survey, all contained 0.01 ounce per ton gold. It should be noted that Adams and Barlow (1910) reported on a number of erroneous assay results reported from an Oregon laboratory at about this time. A homeowner reported to the author that gold-bearing rock, valued at 60 cents per ton at the turn of the century, had been found on lot 27, concession A of Snowdon Township. An assay sample collected by field party personnel and assayed by the Geoscience Laboratories, Ontario Geological Survey, contained 0.03 ounce gold per ton.

Armstrong and Gittins (1968) reported a molybdenite occurrence on lot 1, concession 7 of Glamorgan Township. Disseminated molybdenite flakes occur in gneiss of the Crego Lake Lithodeme at this site. Adams and Barlow (1960) report magnetite and titanium in a rusty gneiss on lots 11 and 12, concession 1, Minden Township. Magnetite is commonly disseminated in this unit (Area B, Figure 1).

Assay samples collected by field party personnel from rusty weathering gneisses in the Denna Lake Structural Complex (Area D, Figure 1) along Highway 121 on lot 33, concession A, of Lutterworth Township, contain anomalous values of a variety of elements, as follows:

Co: 104 ppm

Cu: 155, 250, 520 ppm

Nb: 55, 135 ppm (background 10 ppm)

Sr: 700, 1005, 1060 ppm (background 200-300 ppm)

Y: 40, 150, 155, 175, 865 ppm (background 20 ppm)

Zn: 147, 245 ppm

Zr: 55, 145, 180, 360 ppm (background 30 ppm)

This unit is extensive (Figure 1), and should be further examined for Nb, Y, and Rare Earth Element (REE) mineralization.

The Imperial Mine produced about 500 to 1000 tons of massive magnetite ore in the 1880s, and was one of several magnetite mines present along the Irondale River at this time.

A number of nonmetallic minerals were exploited in the past in the map area. The quarry at Maxwells produced marble in the late 1890s. Some tombstones in the Gelert cemetery were made from marble from this quarry. The quarry at Allsaw (lot 22, concession 5, Minden Township) produced crushed anorthosite for use as road metal (Satterly 1943). The quarry at Armstrong's on Highway 35 (lot 9, concession 9, Minden Township) produced road metal from amphibolitic gneiss of the CMBBZ (Hewitt 1964). Bolender's Quarry at lot 22, concession 14, Snowdon Township, produced about 80 tons of granular material during 1939-1940, to service marble for making stucco dash and concrete (Hewitt 1964). The Orillia Light and Power Company removed about 40 000 ton of granular material from a granite gneiss on lot 5, concession 3, Minden Township, for use in concrete during the construction of a power dam on Minden Lake (Satterly 1943). A number of small quarries have operated on lots 1, 2, and 3, concession 5, of Minden Township, producing over 8500 tons of flagstone and building stone from straight gneiss of the CMBBZ (Hewitt 1964). None of these quarries is currently in operation, but they do indicate the variety of stone materials available for use in the Lochlin area.

Sand and gravel deposits are abundant along the Drag, Burnt, and Gull River systems in the area, and have not been fully exploited in the past. Henderson (1973) briefly summarizes the glacial geology of the Lochlin area.

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23. Anorthosite Studies: Muskoka District, Haliburton and Victoria Counties

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INTRODUCTION

Field work, supported by the Precambrian Geology Section, was undertaken in two field areas within the Central Gneiss Belt, southwestern Grenville Province, to study the nature and occurrence of thin anorthositic units (colour index = 05-30), as part of the requirements towards an M.Sc. degree at the Department of Geology, University of Toronto.

One area is located in the Muskoka-Georgian Bay region, just north of Port Severn, 125 km north of Toronto on Highway 69, in Baxter Township, Muskoka District (Figure 1). Two subparallel anorthositic units cross the highway here and are called the Little Lake units.

The second area is located along the Head River in Digby Township, Victoria County, north of Highway 503 (Figure 2). The area is composed of a folded package of heterogeneous meta-igneous rocks called the Head River Fold Structure (HRFS), and contains a single thin anorthositic unit referred to as the Head River unit (Easton, in press). Two other anorthositic bodies were briefly studied for comparison and are shown on Figure 2.

GENERAL GEOLOGY

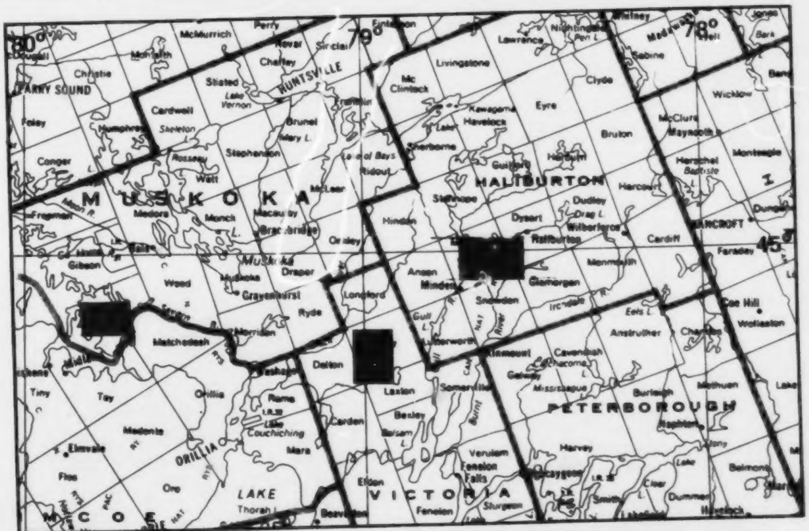
The study of anorthositic units of Middle Proterozoic age in the southwestern Grenville Province has two purposes: (1) to evaluate the economic potential of these units; and (2) to attempt to resolve two different interpretations regarding the origin of these units. Firstly, that the thin, anorthositic units in the southwestern Grenville Province are highly deformed slivers peeled off of a larger parent body during northwest directed thrusting in the region (Davidson *et al.* 1982; A. Davidson, geologist, Geological Survey of Canada, written and personal communication, 1984, 1985). Secondly, that they were emplaced as thin intrusive sills or sheets into a heterogeneous sheeted sill complex at deep crustal levels (Van Berkel and Schwerdtner, in preparation). Knowledge of the emplacement mechanism of these units will assist in evaluation of the mineral potential of these rocks.

A detailed study of these units has shown that: (1) some units are not associated with high strain structural boundary zones and contain abundant relict igneous textures; and (2) those units located within structural boundary zones have a gneissic texture and contain distinctly different features than their less deformed counterparts. Both the Head River unit and the Little Lake units exhibit internal features suggesting they may be moderately deformed intrusive sheets.

Little Lake Area

Two subparallel anorthositic units are found northwest of Little Lake in the Go Home Subdomain of the Muskoka Domain (Davidson *et al.* 1982), and are continuous for 8 km (Figure 1). Southeast of Little Lake, another single unit occurs. It is poorly exposed to north of Coldwater, where it is lost under the Paleozoic cover.

The units northwest of Little Lake are each up to 20 m thick, and are separated by highly strained gabbroic and moderately strained granitoid gneisses. Country rock consists of heterogeneous, migmatitic quartzofeldspathic gneisses of indeterminate protolith. Contacts between the anorthositic units and the quartzofeldspathic gneisses are sharp and parallel the regional foliation. Locally, internal blocky rotation of anorthosite and boudinage of thin layers of anor-


80°
79°
78°
45°
PARRY SOUND
HUNTSVILLE
M U S K O K A
HALIBURTON
PETERBOROUGH
V I C T O R I A
ORILLIA
LAKE
Couchiching
Gravenhurst
Bracebridge
Christie
Foley
Conger
Humphrey
Cardwell
Stisted
Chaffey
Brunel
Stephenson
Watt
Medora
Monck
Macaulay
McLean
Oakley
Draper
Muskoka
Wood
Gibson
Ryde
Morrison
Matchedash
Dalton
Laxton
Carden
Mara
Rama
Orillia
Tay
Tiny
Medonte
Elmvale
Flos
Oro
Thorah I.
Eldon
Fenelon
Fenelon Falls
Verulam
Somerville
Bexley
Balsam L.
Longford
Hindon
Anson
Minden
Snowdon
Glamorgan
Stanhope
Guilford
Havelock
Kawagama
Livingstone
Lawrence
Nightingale
Sherborne
Eyre
Clyde
Bruton
Harburn
Dysart
Dudley
Harcourt
Monmouth
Cardiff
Wilberforce
Haliburton
Sabine
Wicklow
McClure
Maynooth
Herschel
Monteagle
Faraday
BANCROFT
Coe Hill
Wollaston
Chandos
Anstruther
Eels L.
Cavendish
Galway
Burleigh
Methuen
Harvey
Dummer
Belmont
Havelock

LOCATION MAP

Scale ; 1: 1 548 000 or 1 inch to 25 miles

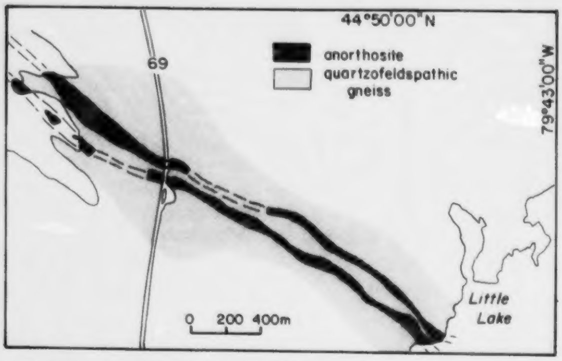

44°50'00"N
anorthosite
quartzofeldspathic gneiss
79°43'00"W
69
0 200 400m
Little Lake

Figure 1. *Anorthositic units on the northwest side of Little Lake. Only the eastern half of the unit is shown. Area lies within the Go Home Subdomain, Central Gneiss Belt. (Project 23.)*

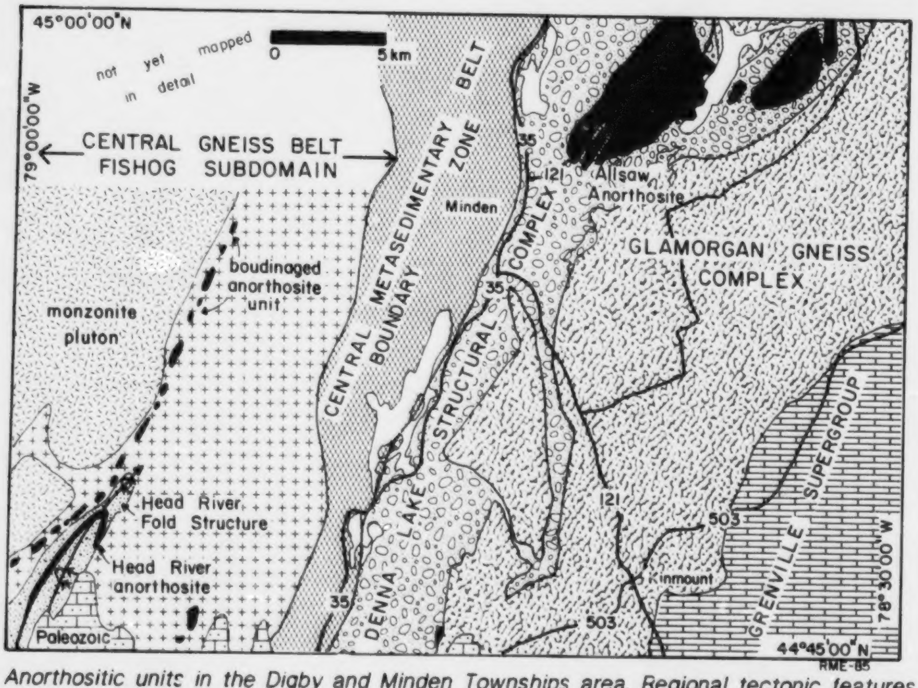

45°00'00"N
0
5km
not yet mapped in detail
79°00'00"W
CENTRAL GNEISS BELT
FISHOG SUBDOMAIN
CENTRAL METASEDIMENTARY BELT BOUNDARY ZONE
Minden
35
121
Allsaw Anorthosite
GLAMORGAN GNEISS COMPLEX
boudinaged anorthosite unit
monzonite pluton
DENNA LAKE STRUCTURAL COMPLEX
Head River Fold Structure
Head River anorthosite
Paleozoic
503
Kinmount
GRENVILLE SUPERGROUP
78°30'00"W
44°45'00"N
RME-85

Figure 2. *Anorthositic units in the Digby and Minden Townships area. Regional tectonic features are also shown. Modified from Easton and Van Kranendonk (1984), Easton (in press). (Project 23.)*

thositic gneiss obscure this relationship (Van Kranendonk 1984).

Relict, igneous textured, layered anorthosite ("leopard rock") is abundant in the Little Lake units and may grade into gneissic textured, gabbroic anorthosite. Leopard rock is prevalent east of Highway 5, with gneissic textured, gabbroic anorthosite predominant west of Highway 5 to Georgian Bay, where the units become more deformed due to folding. No high strain zone is associated with any of the Little Lake units (Davidson *et al.* 1982; Davidson 1984a, 1984b).

Cross-sections across the Little Lake units display a consistent distribution of rock types, commonly showing gneissic textured borders, but recrystallized, relict, igneous textures in the core. Sampling for variation in geochemical signature across the units was undertaken to determine whether or not textural and compositional variations are related. If so, then these units may be moderately deformed layered intrusive sills or sheets.

HEAD RIVER AREA

Three anorthositic units are present in the Fishog Subdomain (Easton and Van Kranendonk 1984). The Head River unit is the best exposed and most continuous unit, and is located within the Head River Fold Structure (HRFS), a heterogeneous sheeted sill complex within the older part of the Fishog Subdomain (Easton, in press). The Head River anorthosite unit is about 8 km long, but only up to 20 m thick, containing lineated rods of hornblende and biotite aggregates. Gabbroic anorthosite makes up about 70% of the unit, with anorthosite comprising the remainder. Minor metagabbro is present.

The Head River unit is interleaved with mafic monzonite to monzodiorite, felsic monzodiorite, migmatitic metagranite, and a thin unit (up to 10 m) of K-feldspar megacrystic metagranite. The associated HRFS, an overturned synform, is intruded by a series of syenogranite sills along the fold axis of the synform. The hinge has an attitude of 110°/80° and the anorthositic unit is broken up and intruded by much granite pegmatite in the nose of the fold. The Head River unit is metamorphosed to amphibolite facies and is thoroughly recrystallized. Clotty hornblende texture represents a minimally deformed meta-igneous feature, and may be used as a minimum regional strain gauge. A 4 cm thick dike of gabbroic anorthosite intrudes dioritic country rock 500 m north of the Head River unit.

The lack of a high strain zone with this anorthositic unit, the moderately deformed, lineated, leopard rock texture, and the presence of a thin gabbroic anorthosite dike, indicate that this unit is an intrusive sheet, and not a tectonically emplaced thrust slice.

Just west of the Head River unit is a zone of local deformation that borders a large monzonite pluton to the west, and may be related to diapiric emplacement of this pluton (Figure 2). Within the border zone of the pluton is a boudinaged anorthosite unit with a maximum thickness of only 20 m and a minimum strike length of 13 km to possibly longer than 30 km. Individual boudins may be up to 1 km long, and are composed of breccia of gneissic and leopard rock-textured anorthosite to gabbro. Blocks within the breccia are separated by granitic pegmatite or sheared gabbroic layers. Blocks having distinctly different preserved strain textures may be separated by no more than a few centimetres of pegmatite. The host rocks are equigranular, recrystallized felsic monzodiorites in which no strain gauges have been preserved. Granitic rocks to the west are moderately deformed along the pluton margin. As with the Head River unit, this boudinaged unit is not found in relation to a structural boundary zone. Also, deformation of thin anorthositic units within highly strained quartzofeldspathic gneisses is inhomogeneous, and is of two types: (1) early ductile flow resulting in lineated leopard rock textures and gneissic gabbroic anorthosite within boudins; and (2) late brittle fracture, forming breccias that juxtapose minimally deformed and highly deformed textures.

OTHER AREAS

Within the Denna Lake Structural Zone (Easton 1983) of the Central Metasedimentary Belt of the Grenville Province in Minden Township, Haliburton County, is a 20 km long anorthosite body called the Allsaw or the Highway 121 Anorthosite. Two smaller bodies lie to the east of the main body (Figure 2), and all are surrounded by calcitic marble tectonic breccia (Easton, this volume). The Allsaw Anorthosite and associated bodies are probably thrust slices, based on the following observations:

(1) Topographic lows within the body and along its margin consist of marble tectonic breccia, suggesting the anorthosite is a thin sheet floating on the marble breccia.

(2) A cross-section measured up a steep slope of the western margin of the Allsaw Anorthosite consists of tens of metres of marble tectonic breccia, then a 10 m thick zone of strongly foliated, completely recrystallized, granular mass of anorthosite, intruded by about 20% of granitic pegmatite which intruded parallel to the regional foliation and is mechanically deformed. Further up section, the foliation diminishes in intensity, the pegmatites are oriented more vertically across the shallow-dipping foliation plane and are less deformed than their more horizontally oriented counterparts down section. Again higher up, the anorthosite has relict igneous plagioclase, and preserves an igneous texture in a massive, non-foliated rock.

(3) Some outcrops in the marble tectonic breccia near the body contain round gneissic anorthosite blocks plucked off the main anorthosite body.

All these features suggest that the Allsaw Anorthosite is a thrust slice, transported over the marble breccia.

STRAIN ANALYSIS

Samples of lineated leopard rock were collected along the length of, and across the Head River anorthosite unit. Strain analysis of these samples should show the amount of strain recorded by the folding event that affected both the Head River unit and the HRFS. As well, strain analysis will help estimate the overall strain recorded by the unit prior to folding. This will help in developing a predeformational geometry for the unit. This geometry can then be used as a guideline for estimating the amount of deformation affecting the gneissic textured, anorthositic units in the high strain zones of the Muskoka-Georgian Bay region. Preliminary estimates indicate that leopard-rock textured anorthosite is estimated to form under strain values in excess of 300% extension, but less than about 900%.

ECONOMIC GEOLOGY

Anorthositic units within the Fishog Subdomain and in the Muskoka-Georgian Bay region are less than 20 m thick. Building stone potential therefore is limited. Recrystallized gabbroic anorthosite of the Central Gneiss Belt weathers to a crumbly mass, and therefore is also unsuitable as building material. The rock, however, is suitable as crushed stone.

In the Denna Lake Structural Complex, the igneous textured core of the main body of the Allsaw Anorthosite has good potential for building stone. It covers a large area and is a coarse, crystalline, hard rock, with an even distribution of mafic material (CI = 10). The Allsaw Anorthosite was quarried near Allsaw in the early 1940s for road metal (Satterly 1943).

Geochemical results to date (R.M. Easton, geologist, Ontario Geological Survey, unpublished data) show low values of normative apatite versus normative ilmenite and magnetite, for both the Head River and Allsaw anorthosite bodies; consequently, they have a low potential for ilmenite-magnetite ore (Emslie 1975). No base or precious metal occurrences have been found within any of the units studied to date. Scapolite is common in the margin of the Allsaw Anorthosite, and may be of interest to mineral collectors.

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24. Computer Software for Geological Applications

Part I: E.J. Ambrose and D. Wright

Geologists, Precambrian Geology Section, Ontario Geological Survey, Toronto.

Part II: E.C. Grunsky

Geologist, Precambrian Geology Section, Ontario Geological Survey, Toronto.

PART I: NEW AND REVISED PROGRAMS FOR THE PDP 11/34

The Precambrian Geology Section of the Ontario Geological Survey has continued to develop and modify its package of computer programs for the examination of geochemical and structural data. Development has also continued on a computerized field note system which combines numerical codes for observed features with unlimited text description. This field note system will allow rapid compilation of information for report writing, and will also be used to archive field notes for later reference.

NEW PROGRAMS (SOURCE LANGUAGE FORTRAN IV; MACHINE PDP 11/34)

CHONDRITE

This program draws chondrite-normalized rare earth element plots. Up to seven samples may be plotted on each diagram and each sample is drawn using a different colour and symbol. A legend is drawn defining the symbol and either sample numbers, comments, or both (*see* Figure 1a).

DENSITY

This program calculates the densities of liquid silicate systems from whole rock analyses following the method of Bottinga and Weill (1970). The density calculations are based on partial molar volumes of the oxide components. The user has a choice of FeO/Fe_2O_3 ratio, final temperature and, if water is to be included in the calculations, a choice of pressure.

GEOCRON

GEOCRON produces tables of geochronological information for Ontario from databases compiled by Easton (1985). The program allows the user to create tables of this information according to reference number, dating method, or NTS location (*see* Figure 1e).

NECRETREV

NECRETREV allows the user to retrieve information from field note data files created using the portable microcomputer field note system (Ambrose *et al.* 1984). When the user selects a category number, for example that for mafic volcanic rocks, the program retrieves all stations at which mafic volcanic rocks were found along with notes taken about those rocks (*see* Figure 1c).

NECSTRUCT

This program retrieves structural data from field note data files that were created using the portable microcomputer field note system. When a category number and, if applicable, a qualifier is entered by the user, stations with corresponding strikes and dips or azimuths and plunges are retrieved from the data file. A new file may be created with this data which may be used later to generate a stereonet plot by calling the STRNET program (*see* Ambrose *et al.* 1984) (*see* Figure 1d).

SAMPLOT

This program plots sample locations at 1:50 000 or 1:15 840 scale. The style, colour, and method of labelling of the points is user defined. Either a UTM grid or a border may be drawn. The input may be from a disk file of either geochemical data or field note data (*see* Figure 1b).

UPDATES ON OLDER PROGRAMS

During the 1983 to 1984 season, a software package was developed which included programs to produce binary and ternary geochemical plots (Ambrose *et al.* 1984). Over the last year several new features have been added to these programs.

The BINARY program now includes options that allow the user to:

1. include Barth-Niggli or CIPW normative minerals in user-defined formulae
2. use logarithmic axes
3. generate a best-fit curve using least squares regression analysis

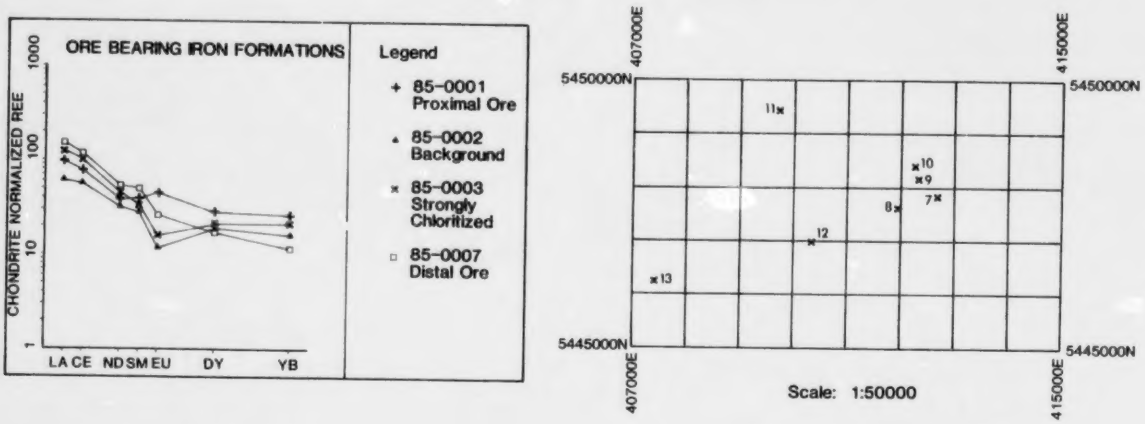
The TERNARY program now includes options that allow the user to define formulae for each apex. These formulae may contain logarithms, nested brackets, major oxide values, trace element values, Barth-Niggli or CIPW normative minerals, numbers, and arithmetic functions (addition, subtraction, multiplication, and division).

SUMMARY

Programs which generate plots use an Industry Standard Plotting Package for a Hewlett Packard 7220C plotter. Source listings, User Guides, and Maintenance Guides for any of these programs are available upon written request (*see* address below). Documentation related to the field note system is also available. For computers other than the PDP 11/34, some modifications may be necessary.

Address

Elizabeth Ambrose
Precambrian Section
Ontario Geological Survey
912 - 77 Grenville Street
Toronto, Ontario
M5S 1B3



a) Chondrite plot

b) Sample location plot

c) Category information retrieval

```
FILE   MA3185.TXT

CATEGORY NUMBER 03 WHICH IS
   Mafic Volcanics

STATION       CATEGORY            COMMENTS
NUMBER         NUMBER

 0564            039      DK GREEN WELL BANDED AMPHIBOLITE
                          EPIDOTE VEINLETS SMALL SWEATS AND
                          PODS OF QTZ FELD MATERIAL  INTRUDED
                          BY QTZ MONZONITE UP TO 3cm WIDE

 0566            038      LEOPARD ROCK FLOW   GNEISSIC AMPHI
                          BOLITE  GRADES INTO FG MSV FLOW
                          2cm FELD PHENOS ON SOUTH PART OF O C

 0567            038      HIGHLY FOLIATED AND CONTORTED FG AND
                          MG XTALINE MAFIC VOLC  AMPHIBOLITIZED
                         HORIZONS OF LEOPARD ROCK
```

d) Structural information retrieval

```
FILE  MA3185 TXT

CATEGORY NUMBER  705
   Cleavage
QUALIFIER
   Fracture


STATION              STRIKE              DIP
NUMBER

 0288                 125                 84
 0289                 108                 60
 0290                 322                 78
 0291                 200                 38
 0294                 100                 70
 0299                 050                 90
 0300                 134                 75
 0306                 108                 76
 0308                 098                 76
 0309                 145                 74
```

e) Geochronology table

```
REFERENCE   AGE/ERR    METHOD  ROCK   LOCATION                NTS   PROV   SOURCE              COMMENT
------------------------------------------------------------------------------------------------------------
253a        1628+/-90    bK    scht   46 22"00'N  81 42"00'W  41I          Lowdon  1960        GSC 59-43, Huronian
166b        1119+/-50    bK    cabt   46 59"00'N  83 18"00'W  41J          Gittins et al. 1967 Seabrook Complex
316b        2282+/-110   bK    sdtd   47 57"00'N  78 22"00'W  31M   ABT    Lowden  1960        GSC 59-78
```

Figure 1. *Sample output produced by the programs: (a) CHONDRITE, (b) SAMPLOT, (c) NECRETREV, (d) NECSTRUCT, and (e) GEOCRN. (Project 24.)*

PART II: IBM COMPATIBLE GEOCHEMICAL AND GRAPHICAL ROUTINES (SOURCE LANGUAGE FORTRAN 77; MACHINE IBM PC)

A number of geochemical subroutines previously described (Ambrose *et al.* 1984) have been converted from Fortran IV source code (originally run on IBM mainframe and PDP 11/34 minicomputer systems) to Fortran 77 for use on IBM PC microcomputers.

The following routines have been designed as stand alone programs or they can be converted into subroutines for use in larger programs. The documentation for these programs is limited to descriptions of the variables and references within the source code; user and maintenance guides are not available. These routines, however, have been designed as simply and clearly as possible so that they may be easily interfaced with other programs.

CHEM

The CHEM subroutine converts weight percent of major oxides into volatile-free equivalents, and cation proportions. It also optionally adjusts the oxidation state of iron according to the convention of Irvine and Baragar (1971).

IRVBAR

This routine classifies volcanic rocks using major oxide chemistry according to the classification scheme of Irvine and Baragar (1971). It requires the use of the CHEM and BARTH routines.

JENSEN

JENSEN classifies volcanic rocks using cation proportions of the major oxide chemistry as outlined by Jensen (1976). It uses the algorithm of Grunsky (1981), and requires the use of the CHEM routine.

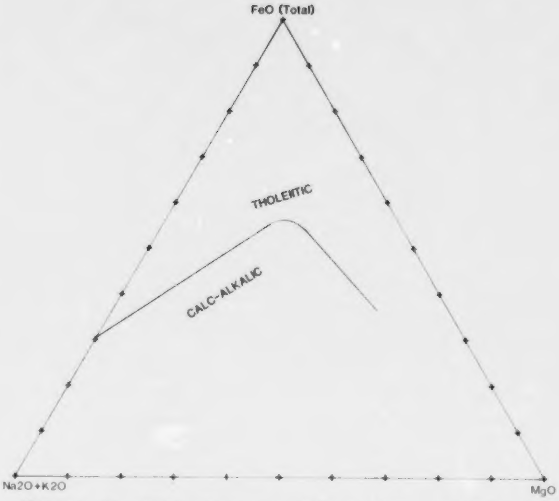


Figure 2. *AFM diagram, after Irvine and Baragar (1971). (Project 24.)*

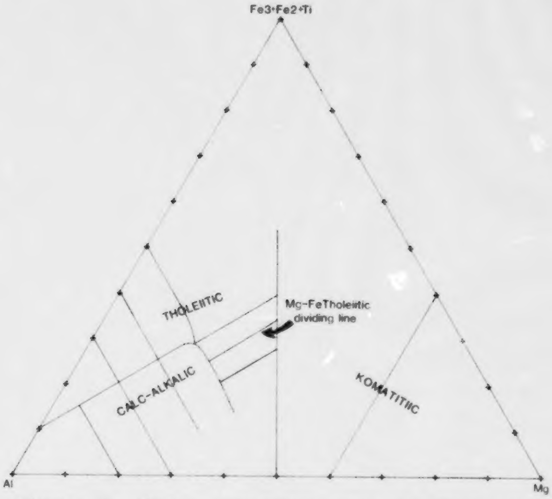


Figure 3. *Cation proportion plot, modified after Jensen (1976). (Project 24.)*

CIPW

This subroutine calculates the C.I.P.W. normative mineral values (based on weight percent formulae) following the procedure of Hutchinson (1974). It requires the use of the CHEM routine.

BARTH

This routine calculates the Barth-Niggli normative mineral values (based on molecular proportions, thus simulating modal abundances) as outlined by Hutchinson (1974). It requires the use of the CHEM routine.

IRVBND

This routine plots the calc-alkalic - tholeiitic boundary curve on the AFM diagram as outlined by Irvine and Baragar (1971) (Figure 2). IRVBND also optionally reads in the chemical data, calculates $Na_2O + K_2O$, FeO (total), MgO, and plots calculated points on the diagram. The routine will also calculate the rock name based on the chemistry. It uses Industry Standard Plotting Package subroutines for the graphical output, and also requires the routines-CHEM, IRVBAR, and BARTH.

JENBND

This subroutine plots the curves of the ternary diagram devised by Jensen (1976) (Figure 3). It also optionally calculates the rock name and ternary values ($AlO_{1.5}$, $FeO_{1.5}$-FeO-TiO_2, MgO) from chemical data, and plots the ternary values on the diagram. It uses Industry Standard Plotting Package subroutines for the graphical output. Other subroutines required are CHEM and JENSEN.

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25. Preliminary U-Pb Zircon Ages from the Lumby Lake-Marmion Lake Area, Districts of Kenora and Rainy River

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[2]Department of Geology and Geophysics, University of Hawaii, Honolulu, Hawaii, U.S.A. (formerly Geologist, Precambrian Geology Section, Ontario Geological Survey, Toronto).

INTRODUCTION

Sampling of volcanic and plutonic rocks in the area of Lumby Lake and Marmion Lake for zircon geochronology was carried out in 1984. The Lumby Lake area had been mapped in detail during the two previous seasons (Jackson 1982, 1983). The geochronological investigation was initiated in order to determine the age of volcanism in the Lumby Lake greenstone belt and the age relationship between felsic volcanic rocks and the more extensive granitoid rocks of the Marmion Lake batholith.

Four samples were collected:

1. A quartz-phyric rhyolite flow in the lower cycle of the Lumby Lake volcanic sequence.
2. A subvolcanic quartz porphyry, also from the lower part of the sequence.
3. A sample of banded tonalite gneiss from the central part of the Marmion batholith.
4. A sample of massive tonalite from the rim of the Marmion batholith.

Sample locations are shown in Figure 1.

This area was selected for geochronology partly because of work by R.I. Thorpe at the Geological Survey of Canada, in which Pb-Pb data obtained from galena in a Cu-Zn occurrence near Lumby Lake indicated a pre-Kenoran age of mineralization (R.I. Thorpe, Geologist, Geological Survey of Canada, personal communication, 1985).

GENERAL GEOLOGY

The Lumby Lake greenstone belt occupies the northern margin of the Marmion block, a segment of crust located in the south central part of the Wabigoon Subprovince (Schwerdtner *et al.* 1979). The Marmion block is bounded on the west by faults extending from the Steep Rock Lake area through Red Paint Lake, and on the south by the Quetico Fault (Figure 1).

The Lumby Lake belt is a folded supracrustal sequence consisting predominantly of mafic metavolcanics with numerous thin felsic metavolcanic units. The felsic metavolcanics occur in at least two horizons within the sequence. South of the supracrustal sequence is the Marmion Lake batholith, which has a pre-tectonic core phase of banded tonalite-granodiorite gneiss. Its western margin is intruded by a massive tonalite-granodiorite pluton which extends from the Lumby Lake area in the north to the Steep Rock Lake area in the south. The contact between

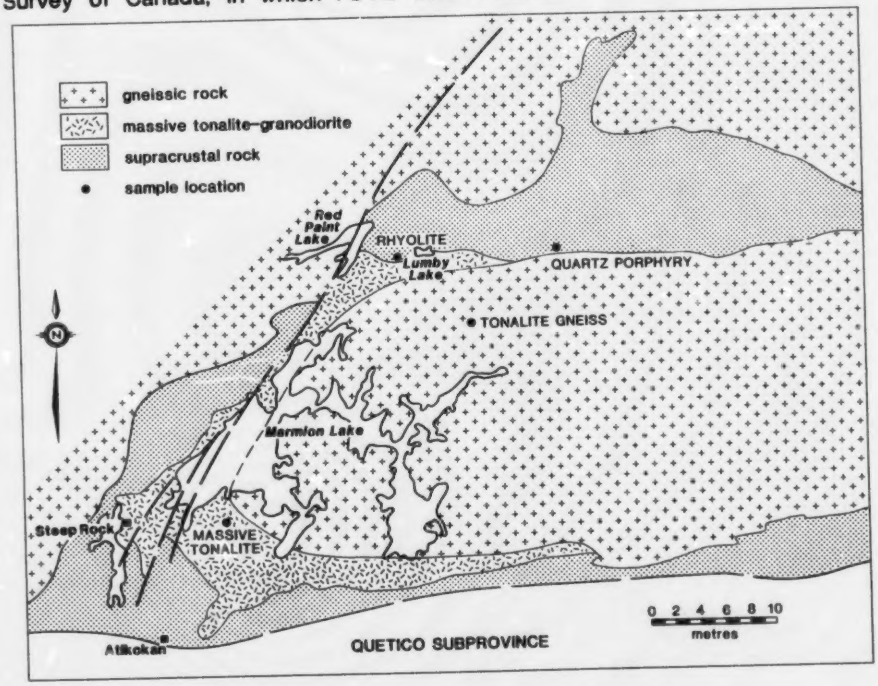

Figure 1. Geological map of the Marmion Lake area showing sample locations. (Project 25.)

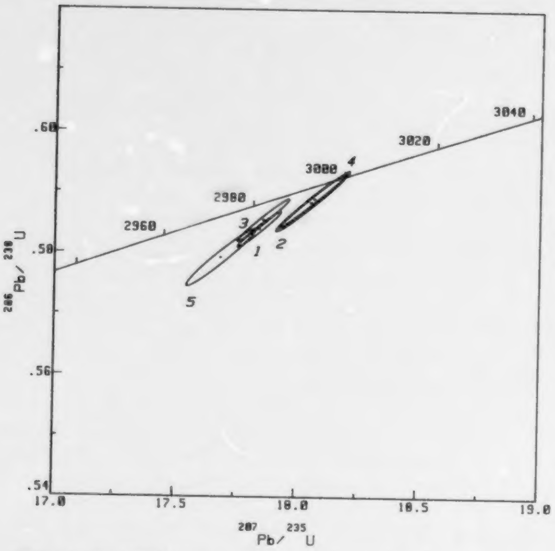

Figure 2. *U-Pb concordia plot showing zircon analyses from the Lumby Lake area. Error ellipses represent 95% confidence levels. (1-3) - Lumby Lake rhyolite; (4) - subvolcanic quartz porphyry; (5) - tonalite gneiss from the Marmion batholith. (Project 25.)*

the supracrustal rocks in the Lumby Lake area and the subjacent granitoid rocks is obscured by numerous gabbro-diorite sills and dikes.

RESULTS

Isotopic analyses were carried out at the Jack Satterly Laboratory of the Royal Ontario Museum, Toronto. Although all samples yielded adequate quantities of zircon, extremely small zircon fractions, 20 to 90 micrograms, were selected. This was done in order to obtain high quality crystals, which should give the most concordant results.

The rhyolite sample was collected in the vicinity of Lumby Lake (Figure 1), where the felsic metavolcanics are best developed. The unit is locally mineralized, and attains 200 m in thickness. All analyses are concordant or nearly so (Figure 2), and give ages ranging from 2990 Ma to 2999 Ma. This age spread exceeds normal experimental error. It may be due to extraordinarily high analytical errors resulting from the small size of the zircon fractions, or the age spread may be the result of geological factors, such as disturbance during the Kenoran event at about 2700 Ma to 2750 Ma or the presence of slight amounts of inheritance in the isotopic system.

A single zircon fraction from the subvolcanic quartz porphyry within the greenstone belt is nearly concordant and gives an age of 2999 Ma. This is indistinguishable from the age of the rhyolite (Figure 2).

A single fraction from the tonalite gneiss is slightly disconcordant and gives an age of 2991 Ma, which again is contained within the spread of the rhyolite data (Figure 2).

A zircon fraction from a sample of massive tonalite gives a somewhat younger $^{207}Pb/^{206}Pb$ age of 2929 Ma. This fraction is more discordant than the others (Figure 3).

DISCUSSION

The age results from the Lumby Lake rhyolite sample agree very well with the results of Pb-Pb isotopic analyses carried out on galena from a mineralized area of this same unit (R.I. Thorpe, Geologist, Geological Survey of Canada, personal communication, 1985). This conclusively demonstrates the presence of pre-Kenoran crust within the Wabigoon Subprovince.

The subvolcanic quartz porphyry is from another felsic unit contained within the lower horizon and was therefore thought to be correlative with the unit at Lumby lake. This is supported by the age of 2999 Ma.

The tonalite gneiss gives a similar age to the supracrustal rocks of 2991 Ma. This age may be slightly too young because of the possibility of disturbance during metamorphism and diapiric remobilization of the batholith. It indicates that a substantial block of crust within the Wabigoon Subprovince is about 3 Ga old.

Interpretation of the 2919 Ma age from the massive tonalite phase is more problematical because of its discordance. The uranium concentration of all zircon fractions analyzed was <80 ppm, which would normally indicate negligible amounts of lead loss due to secondary, low temperature processes. The possibility, therefore, arises that this result may represent the effect of inheritance. A mixing line drawn through the data point representing the massive tonalite and intersecting concordia at 2700 Ma which is a common age for late-tectonic plutons in the Wabigoon Subprovince, has an upper concordia intersection of 3550 Ma (Figure 3). Therefore, if the tonalite were intruded during the Kenoran event, it may have involved partial melting of sialic crust older than any yet found in the Superior Province. On the other hand, if there is no inheritance, then the 2919 Ma age on what is probably a syn- to late-tectonic pluton would indicate a major deformational event prior to the Kenoran event. More analyses are required to resolve this question.

Extensive geochronological investigations previously carried out in the Wabigoon Subprovince have shown a narrow range of ages from 2755 Ma to 2695 Ma (Davis *et al.* 1982; Blackburn *et al.* 1985). Furthermore, substantial pre-Kenoran crust in the Superior Province south of the English River-Wabigoon Subprovince boundary has never been reliably dated. Thus far, the most important result of this investigation has been to prove that significantly older crustal segments are present in the Wabigoon Subprovince.

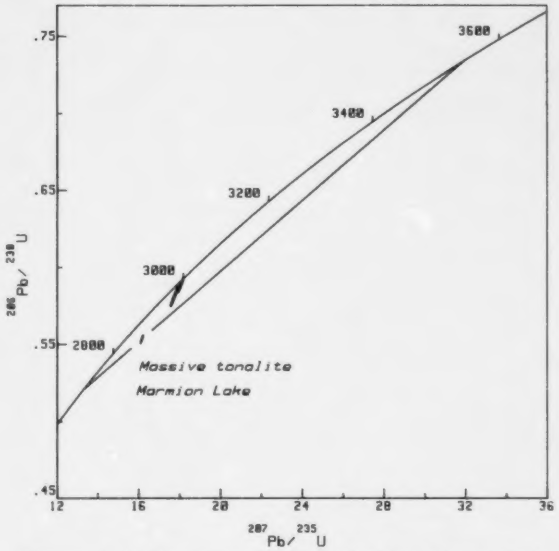

Figure 3. *U-Pb concordia plot showing zircon analyses for all samples. A model mixing line is drawn through the massive tonalite data point and constrained to intersect concordia at 2700 Ma. Its upper intersection is 3550 Ma. (Project 25.)*

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26. The Wabigoon Diapiric Axis as a Basement Complex

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This article summarizes a number of structural and isotopic features which suggest that at least a portion of the Wabigoon Diapiric Axis (WDA) defined by Edwards and Sutcliffe (1980) is an anomalous part of the Wabigoon Subprovince and may represent a basement complex.

In the Superior Province, the fundamental architecture is alternating long linear granite-greenstone terranes representing proximal volcanism and sedimentation. These granite-greenstone terranes alternate with temporally equivalent metasedimentary belts representing minor distal volcanism and major clastic sedimentation (Young 1978). The metasedimentary belts are usually of high metamorphic rank and include granitoids derived from partial melting of metasediments and major potassic batholiths derived from melting of earlier tonalites (Beakhouse 1985). The metasedimentary belts can include basement complexes of meta-igneous gneisses and relict supracrustal rocks as in the case of the Winnipeg River Belt, the southern half of the English River Subprovince (Beakhouse 1985). Not all metasedimentary belts include basement complexes. For example, the Quetico Belt shows no sign of basement lithologies (Percival 1985).

Basement complexes are known in Shield areas the world over, examples include the Limpopo Belt (Barton 1983), areas within the Hoggar area of Algeria (Bertrand and Laserre 1976), the English River Subprovince (Beakhouse 1985), and the Thompson Belt of northwest Manitoba (Green *et al.* 1985). In most of these areas, there is at least some evidence of multiple orogenic events in basement complexes suggesting many metasedimentary belts are also mobile belts.

Basement complexes in shield areas have a variety of genetic histories. The Thompson belt in northwestern Manitoba has been produced by the collision of the Archean Superior Craton with an island arc terrane in a well accepted plate tectonic scenario (Green *et al.* 1985). In contrast, the Limpopo Belt represents basement, metasedimentary terrane, and reworked granite-greenstone terrane of the Kaapvaal and Rhodesian cratons in a mobile belt produced by craton-craton collision (Light 1982). The distinguishing features of Archean mobile belts are the lack of preserved oceanic crust, a protracted history of orogeny, and the presence of sialic basement (Barton 1983; Beakhouse 1985).

Important features of basement complexes as exemplified by the Limpopo belt (Light 1982; Barton 1983) are the fact that they are composed of a number of domains each characterized by unique lithologic associations representative of metasedimentary terrane, granite-greenstone terrane, and variable amounts of basement in the form of high metamorphic rank gneissic rocks. Each domain has had a unique structural and metamorphic history often spanning a protracted interval for example >4000 Ma to about 2000 Ma in the case of the Limpopo Belt (Watkeys 1983; Barton *et al.* 1983).

THE WABIGOON DIAPIRIC AXIS

The central part of the Wabigoon Subprovince has been recognized by Edwards and Sutcliffe (1980) as distinctive in structure and type of plutonism. They termed the area the Wabigoon Diapiric Axis and characterized it as having an abundance of gneiss domes, arcuate intrusions, and late (circular) granitoids. Recent mapping by Percival (1983) has confirmed the fact that the Wabigoon Diapiric Axis consists of largely tonalite-granodiorite gneiss with foliated to massive granodiorite gneiss, foliated to massive tonalite, and minor massive granitic rocks. Morgan (1979) noted that foliations present in the diapiric axis cut across metavolcanics of the Finlayson Lake greenstone belt, the on-strike continuation of the Lumby Lake greenstone belt (Jackson 1982, 1983; Davis and Jackson 1985). R. Thorpe (Geologist, Geological Survey of Canada, personal communication, 1985) in a large-scale reconnaissance Pb-Pb isotopic research program noted a 2.9 Ga Pb-Pb model age for Lumby Lake galenas. Recent U-Pb zircon geochronological data (Davis and Jackson, this volume) for the Marmion gneiss and the Lumby Lake greenstone belt indicates ages of nearly 3.0 Ga. These ages are significantly older than any previously reported for Wabigoon Subprovince volcanism or plutonic rocks.

In the light of this background, it is interesting to note that neither the Obonga Lake nor the Garden Lake greenstone belts (Figure 1) nor the potentially related foliated tonalites with supracrustal inclusion trains (*see* Figure 1 derived in part from Percival 1983) cross the diapiric axis. The eastern end of the Sturgeon Lake belt terminates against the western edge of the diapiric axis terrane in a complex arcuate pattern at Mountairy Lake. The eastern edge of the classical Wabigoon Subprovince terrane at Bending Lake which is largely ironstone does not persist across the diapiric axis. In locations where greenstone-granite terranes abut metasedimentary gneiss belts such as the Uchi-English River transition (Thurston and Breaks 1978; Thurston 1981), elements of granite-greenstone terrane stratigraphy can be traced into metasedimentary gneiss terrane. Therefore, by example (above) and analogy with Watkeys (1983), the edges of the Wabigoon Diapiric Axis terrane can be seen to differ from granite-greenstone to metasedimentary gneiss transitions. This margin may represent an unconformity between the WDA as a basement complex and the younger Wabigoon Subprovince or a faulted contact between either basement and cover or two terranes with separate geologic histories. By analogy with the various interdomain contacts of the Limpopo Belt (Watkeys 1983;

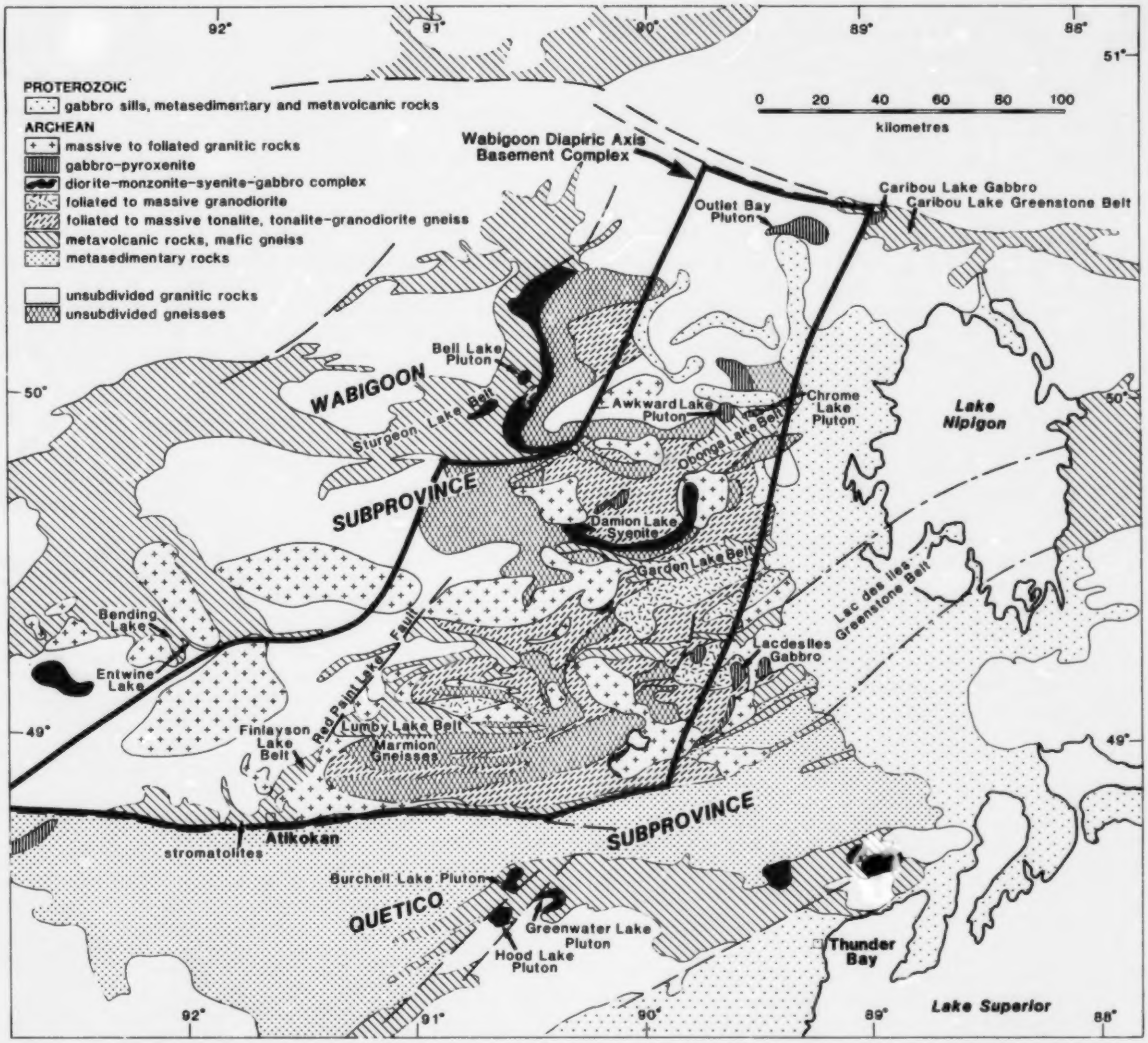
92°
91°
90°
89°
88°
51°
50°
49°
PROTEROZOIC
gabbro sills, metasedimentary and metavolcanic rocks
ARCHEAN
massive to foliated granitic rocks
gabbro-pyroxenite
diorite-monzonite-syenite-gabbro complex
foliated to massive granodiorite
foliated to massive tonalite, tonalite-granodiorite gneiss
metavolcanic rocks, mafic gneiss
metasedimentary rocks
unsubdivided granitic rocks
unsubdivided gneisses
0 20 40 60 80 100
kilometres
Wabigoon Diapiric Axis Basement Complex
Caribou Lake Gabbro
Caribou Lake Greenstone Belt
Outlet Bay Pluton
Bell Lake Pluton
WABIGOON
Sturgeon Lake Belt
Awkward Lake Pluton
Chrome Lake Pluton
Obonga Lake Belt
Lake Nipigon
SUBPROVINCE
Damion Lake Syenite
Garden Lake Belt
Lac des Iles Greenstone Belt
Bending Lake
Entwine Lake
Red Paint Lake Fault
Lacdesiles Gabbro
Finlayson Lake Belt
Lumby Lake Belt
Marmion Gneisses
Atikokan
stromatolites
SUBPROVINCE
Burchell Lake Pluton
QUETICO
Greenwater Lake Pluton
Hood Lake Pluton
Thunder Bay
Lake Superior

Figure 1. *Generalized geological map of the Wabigoon Diapiric Axis Basement Complex. Geology after Ayres et al. (1971) and Percival (1983). Post-tectonic felsic and alkalic intrusions are: BL = Bell Lake, SN = Sturgeon Narrows (Sage 1983), EL = Entwine Lake (Davies 1965), HL = Hood Lake, BL = Burchell Lake, GL = Greenwater Lake (Stott 1985), LDI = Lac des Iles Intrusion (Sutcliffe 1985), SLDI = intrusions south of Lac des Iles (Pye 1968), DL = Damon Lake Syenite (Percival 1983), AL = Awkward Lake Gabbro (Thurston 1967), CL = Chrome Lake intrusion (Thurston 1967), OB = Outlet Bay Pluton (Sutcliffe 1979), CG = Caribou Lake Gabbro (Sutcliffe 1980). The suggested correlation of the Beardmore-Geraldton Greenstone Belt with the Lac des Iles Greenstone Belt is derived from 1:1 000 000 aeromagnetic data. (Project 26.)*

Light 1982) and the Ear Falls-Manigotagan sedimentary terrane to Winnipeg River Belt basement complex contact (Beakhouse 1985), the margin is thought to represent a faulted contact. More evidence on this point is presented later.

From the above it is concluded that the Obonga and Garden Lake greenstone belts are part of the WDA terrane and are not Wabigoon Subprovince belts. However, the Lac des Iles greenstone belt can be traced aeromagnetically across Lake Nipigon to correlate with Wabigoon Subprovince stratigraphy in the Beardmore-Geraldton area.

Joliffe (1955) postulated that the classical Wabigoon Subprovince stratigraphy in the Atikokan area was deposited unconformably upon a granitoid basement. Recent work by Wilks and Nisbet (1985) have shown deposition of stromatolitic carbonates forming the base of the lower of two volcanic cycles in the Atikokan area to have been deposited in shallow water on granitoid basement. Recent work by Stone (D. Stone, Geologist, Atomic Energy of Canada

Limited, personal communication, 1985) has shown three to four additional examples of this basement-greenstone unconformity in the Atikokan area. Geochronological work (Davis and Edwards 1982, Davis *et al.* 1982, Davis and Trowell 1982) has shown that Wabigoon supracrustal rocks and granitoids range from 2755 Ma to about 2680 Ma in age.

Several types of post-tectonic intrusions occur along the edges of the Wabigoon Diapiric Axis:

1. Mafic-ultramafic plutons: a) east margin of the diapiric axis: Lac des Iles (Sutcliffe, this volume); the string of plutons south of Lac des Iles (Pye 1968); the Awkward Lake gabbro and the Chrome Lake serpentinite (Thurston 1967); dioritic bodies at Caribou Lake in the Armstrong area (Sutcliffe 1980), and the Caribou Lake gabbro (Sutcliffe 1979).
2. Syenites and alkalic plutons: a) east margin of the diapiric axis: Damon Lake syenite (Percival 1983), Burchell Lake Pluton, Hood Lake Pluton, and Greenwater Lake Pluton (Stott 1985); b) west margin of the diapiric axis: Bell Lake intrusion (Trowell 1983); Squaw Bay and Sturgeon Narrows Complex (Sage 1983); Entwine Lake Complex (Davies 1965).

This concentration of post-tectonic alkalic and mafic-ultramafic plutonism is often concentrated along crustal-scale fracture zones (Percival and Card 1985).

MODEL

These seemingly disparate pieces of evidence may be interrelated by considering the central part of the Wabigoon Diapiric Axis to be a separate terrane tentatively named the Wabigoon Diapiric Axis Basement Complex on the basis of:

1. *Discordant tectonic grain* - The Wabigoon Diapiric Axis is characterized by a general regional northeast trend that truncates the east-west to east-northeast trends of the Wabigoon Subprovince volcanic belts.
2. *Local unconformable relationships* - Local unconformities between Wabigoon Subprovince volcanic sequences and underlying rocks of the Wabigoon Diapiric Axis.
3. *Contrasting absolute ages* - Parts of the Wabigoon Diapiric Axis and at least one of the infolded volcanic belts (Lumby Lake) approach 3.0 Ga and contrast sharply with ages for volcanic-plutonic complexes west of the diapiric axis (2700 Ma to 2755 Ma).
4. *Concentration of distinctive intrusive rocks* along its margins suggesting possible crustal-scale fracturing.
5. *Evidence for multiple deformations* - The data of Davis and Jackson (1985) and Morgan (1979) also suggest the terrane has been multiply deformed with a pre-Kenoran orogenic event postulated on isotopic and structural grounds, and a Kenoran orogenic event based on the presence and age of post-tectonic plutons (Davis and Edwards 1982). This establishes the east and west limits of the Wabigoon Diapiric Axis Basement Complex as shown in Figure 1. It is unknown what the character of these boundary zones is. By analogy with the boundaries of domains within the Limpopo Belt (Watkeys 1983), the authors may expect the boundaries to be crustal-scale shear zones. Representative of this sort of border zone is the northeast-trending Red Paint Lake fault zone (Jackson 1983).

The Wabigoon Diapiric Axis Basement Complex may have had a structural history independent of the adjacent Wabigoon Subprovince (Morgan 1979; Stott 1985). As well, consideration of the data of Percival (1983) shows both batholithic terrane and granite-greenstone enclaves to have structural trends and fold styles at variance with the Wabigoon Subprovince and that greenstone enclaves do not continue into or link up with Wabigoon Subprovince greenstone belts.

The Wabigoon Diapiric Axis Basement Complex is probably a feature of large scale crustal proportions given the concentration of alkalic and mafic-ultramafic intrusions along the eastern and western margins. The Basement Complex is about 80 km wide with the western margin in the vicinity of the Red Paint Lake fault (Jackson 1983) or the eastern terminus of the Sturgeon Lake greenstone belt at Mountairy Lake. The eastern margin is in the vicinity of Lac des Iles and the western end of the Caribou Lake greenstone belt (Sutcliffe 1979). The southern margin is difficult to define. The evidence of Percival (1985) suggests the Quetico belt is a relatively young feature. While the Wabigoon Diapiric Axis Basement Complex could extend south beyond the Quetico fault, evidence for this is limited. The northern limit of the basement complex is possibly as far north as the northwest-trending fault at Wabakimi Lake northwest of Armstrong.

Given all of the above features, the Wabigoon Diapiric Axis Basement Complex gneissic rocks and supracrustal enclaves may be largely >2750 Ma in age. The closest analogue to the Wabigoon Diapiric Axis Basement Complex is the Limpopo Belt of Southern Africa. In any comparison, however, it seems obvious that parts of the Limpopo Belt expose rocks of greater antiquity (Barton *et al.* 1983) and in general the exposed crustal level in the Limpopo is probably deeper given the deformation pattern, proportion of metavolcanics, and high metamorphic rank throughout compared to the Wabigoon Diapiric Axis area.

In conclusion, the evidence presented indicates that at least part of the Wabigoon Diapiric Axis acted as basement to Kenoran-age rocks of the Wabigoon Subprovince or that it underwent a geologic history independent of these rocks, and therefore comprises either a basement-cover relationship or forms a distinct subprovince. Research is currently underway to place more precise boundaries on the Wabigoon Diapiric Axis Basement Complex and to obtain radiometric ages of selected units within the complex.

ACKNOWLEDGMENTS

The authors wish to acknowledge the critical reading of the manuscript by G.P. Beakhouse and H. Wallace under real deadline pressure. Discussions with G. Beakhouse and R.H. Sutcliffe have helped in the thought process.

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ENGINEERING AND TERRAIN GEOLOGY PROGRAMS

Summary of Activities 1985, Engineering and Terrain Geology Section.

Owen L. White

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INTRODUCTION

In 1985, the staff of the Engineering and Terrain Geology Section were involved in field investigations in 15 localities across northern and southern Ontario: eight by leading field party investigations themselves, or by providing on-site services or supervision in conjunction with private sector contractors. Only one new field project was initiated during 1985 under the Hydrocarbon Energy Resources Program (HERP) which in this current year has been in the final of a five year program.

In eastern Ontario, P.J. Barnett (Project 27) concluded the study of the Quaternary geology of Renfrew County by completing the mapping of the Golden Lake and Pembroke map areas. The areal extent of the Champlain Sea and positions of several arcuate moraines representing the standstill positions of the waning glacier were identified in the Ottawa and Bonnechere River valleys. Abundant quantities of sand and gravel in ice contact deposits and Champlain Sea deltas and fans were identified in several localities throughout the map areas.

In the Brampton area, P.F. Karrow (28) continued Quaternary geology mapping commenced in 1984. Most of the activity this year was in part of the extensive Halton Till plain, covered in part by the glaciolacustrine sediments of Lake Peel. Quantities of sand and gravel identified along the valley of the Credit River are overlain by the Halton Till but there is some evidence to suggest that these useful economic deposits may be present over an extensive area extending well back from the Credit River valley.

In the Hemlo area, R.S. Geddes, A.F. Bajc, and F.J. Kristjansson (29) completed the mapping of the surficial deposits in the Marathon, Manitouwadge, and White River areas to complete the mapping of a group of 5 map areas in the Hemlo area. This basic Quaternary mapping has not only provided the base data for an extensive assessment of the aggregate resources of the area, but has provided the framework for the development of a statement on exploration models in general and clearly demonstrates the appropriate exploration techniques to be used in various areas of the Hemlo region. Furthermore, these exploration models are directly applicable to other areas provided a fundamental knowledge of the local Quaternary geology is already available. Four research projects at the University of Western Ontario and the University of Waterloo have been initiated following the Quaternary mapping by Geddes and his colleagues.

Cockburn Island, located in the northern portion of Lake Huron and directly west of Manitoulin Island was the base for a field party led by Rainer Wolf (S30) which mapped the Paleozoic rocks on the island prior to the drilling by Bradley Brothers Limited of a hole down into the Precambrian basement. The drillhole, located at the south end of the island, provided 521 m of continuous NQ core over the whole Paleozoic sequence from the Middle Silurian Amabel Formation and 30 m of Precambrian rock. This mapping and drilling on Cockburn Island has helped to fill the geological information gap between Manitoulin Island and St. Joseph Island.

Early in 1985, Golder Associates managed for the Ontario Geological Survey the drilling by Longyear Canada Incorporated of a drillhole at Onakawana in the Moose River Basin (34). The purpose of the drillhole was to acquire a reference core from the same location from whence a similar core was obtained in 1930. The original core is no longer available and the interpretation of recent surface mapping and drilling in the general area is hampered by the lack of the original core and the stratigraphy based on it. The 1985 drillhole was taken to a depth of 321 m with 299 m of Mesozoic, Paleozoic, and Precambrian core recovered.

Aggregate assessment projects (31,32,33) were again concluded in both northern and southern Ontario with R. Gorman in charge of investigations in several townships in five counties in southwestern Ontario, and G. Jones and M. Gauvreau assessing sand and gravel deposits in the Sudbury and Espanola areas.

The assessments in southwestern Ontario were part of the ongoing activity to provide basic sand and gravel information to municipalities designated under the Pits and Quarries Act (1971). Several of the townships investigated have significant supplies of good quality sand and gravel but several townships in Kent, Middlesex, and Perth Counties lack good quality aggregate in quantities suitable for extensive commercial development. The bedrock in the areas investigated is either of unsatisfactory quality or covered by an uneconomic layer of glacial drift. West Wawanosh Township in Huron County and Amabel Township in Bruce County have good supplies of sand and gravel but the bedrock in West Wawanosh is covered by a thick deposit of drift and cannot be considered as a potential resource. In Amabel Township, five quarries have been established to produce building and ornamental stone though none are producing crushed stone.

The aggregate assessment in the Espanola area was undertaken by G. Jones and M. Gauvreau at the request of the Espanola District Office (MNR) to assist in land use plannng operations. Significant deposits of sand and gravel were identified in six of the seven townships investigated but some deposits may include rock types which may cause chemical reactions with the cement in concrete exposed to moisture and salt. The investigation of twenty townships to the northwest of Sudbury was initiated following the recognition of a severe alkali-aggregate problem in the Sudbury area and a shortage of non-reactive aggregate in the commercial pits in the area. For the most part, the area investigated contains an abundant supply of aggregate and although most deposits contain some of the objectionable sandstone, argillite, and wacke of the Huronian Supergroup, decisions on the potential usefulness of the deposits await the results of laboratory testing.

As in previous years, Quaternary geologists of the Engineering and Terrain Geology Section have participated in interdisciplinary field parties, both to provide basic Quaternary geology data on the various areas and to carry out studies to show the potential for the use of Quaternary geology in mineral exploration operations. P.F. Finamore (S54) again was part of the field party mapping in the Opapimiskan Lake area. Quaternary studies in 1985 were concentrated in the Donnelly River, Mawley Lake, Forester Lake and Opapimiskan Lake areas with some extra studies in the North Caribou Lake area.

Lodgement till, glaciofluvial and glaciolacustrine deposits are the dominant drift sediments in the area and were investigated in a series of bedrock dispersion studies which concentrated on iron formation float. Dispersion trains were more readily recognized in the western part of the area as compared with the eastern part and Finamore concludes that this situation may represent a variation of glacial dynamics in the area.

In northeastern Ontario, C.L. Baker, K.G. Steele, and M.B. McClenaghan (S57,S63) investigated the heavy mineral content and geochemistry of tills and esker deposits in two projects as part of the interdisciplinary Black River-Matheson Project (BRIM). Backhoe equipment was used to obtain samples in thin drift areas but a sonic drill was used in thicker drift locations. From the 177 backhoe sites, 144 till samples were taken. In 1984, 42 holes were drilled and in 1985, 60 holes were completed. The samples were (or are being) processed for heavy minerals and gold grains. Geochemical analyses were conducted on both the heavy minerals and the till matrix. Preliminary results were published in December 1984 and further results are expected in the next few months. The results have been related and will be related to glacial stratigraphic units which have been developed with drift exploration programs in mind.

In the investigation of the esker deposits, all sampling was carried out with assistance of backhoes. This project will attempt to determine the significance of sampling the various parts of the esker to determine the relationship between esker sediment and bedrock provenance and to determine the relationship between esker sediment mineralogy and the adjoining till matrix mineralogy. As with the till project, the esker sediments will be examined for gold and other heavy minerals with the heavy minerals "bulk" sample being analyzed for gold and trace elements. The fine fraction of the esker sediment is also to be analyzed for trace elements and whole rock geochemistry.

The results of the drilling of the stratigraphic holes in the Paleozoic rocks together with the drilling for the till and esker sampling projects will be published within a few weeks of the release of this summary.

27. Quaternary Geology of the Golden Lake (31 F/11) and Pembroke (31 F/14) Areas, Renfrew County

P.J. Barnett

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INTRODUCTION

Additional field investigations were carried out in the Golden Lake and Pembroke map areas during August, 1985, prior to the preparation of preliminary Quaternary geology maps for these areas. Initial mapping in these areas was undertaken in 1978 and 1979, respectively (Barnett 1978, 1979).

The Golden Lake and Pembroke areas are located between Latitudes 45°30'N and 46°00'N, and Longitudes 77°00'W and 77°30'W. The communities of Killaloe Station, Eganville, Pembroke, and Petawawa are located within the areas mapped.

The physiography, Quaternary geology, and economic geology of these map areas have been summarized previously (Barnett 1978, 1979), and therefore only the main findings of this past summer's work will be highlighted here.

The style of deglaciation within the Ottawa River valley and the Bonnechere River valley varied greatly.

In the Ottawa valley, a tongue or lobe of active ice was in direct contact with the Champlain Sea. This resulted in a series of arcuate moraines (Figure 2), ice marginal deltas and subaqueous fans, as well as the blanket of fine-grained marine sediments. The areal extent of the Champlain Sea, or its "limit" as defined by shoreline features and "wash" limits, is plotted on Figure 1.

In the Bonnechere valley ice-disintegration features, such as eskers, esker fans, kames, and hummocky topography, are common. Several positions or stand-stills of the glacier margin can be identified (Figure 2). During deglaciation the ice margin trended, generally, east-west.

The areas of hummocky topography can be composed of ice-contact stratified drift or very bouldery, sandy, till. Hummocky topography in this area also results from the differential weathering of the bedrock, particularly in areas of marble.

ECONOMIC GEOLOGY

Large amounts of sand and gravel occur in ice-contact stratified drift and outwash deposits around Golden Lake, Wilber Lake, Green Lake, and in Champlain Sea deltas and fans in the Micksburg area. Champlain Sea shoreline deposits tend to be thin and composed of primarily sand or gravelly sand.

The Ministry of Natural Resources, Eastern Region (in preparation), has prepared an inventory of the sand and gravel deposits within Renfrew County, which includes this area.

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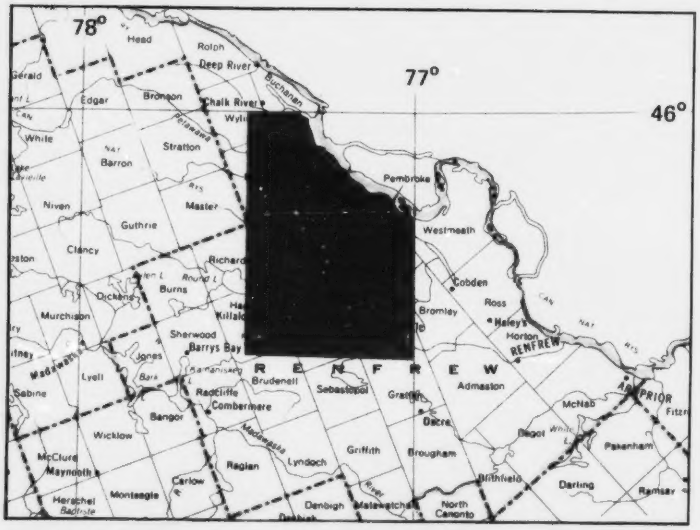
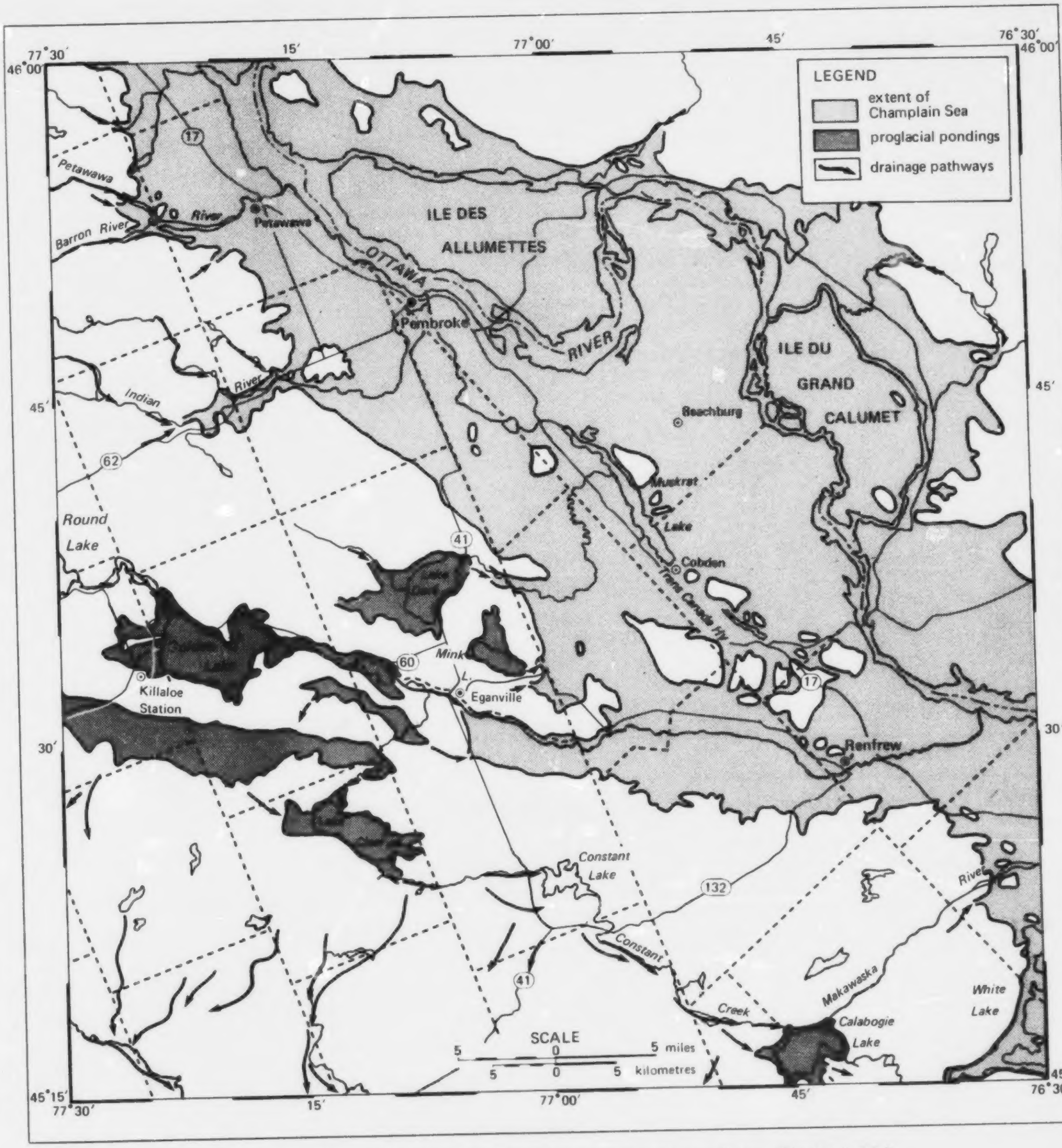

78°
77°
46°
Head
Rolph
Deep River
Buchanan
Edgar
Bronson
Chalk River
White
Barron
Stratton
Petawawa
Pembroke
Niven
Master
Guthrie
Westmeath
Clancy
Richards
Burns
Cobden
Dickens
Ross
Murchison
Bromley
Haley's
Horton
Sherwood
Barrys Bay
Killaloe
RENFREW
Jones
Lyell
R E N F R E W
Brudenell
Sebastopol
Grattan
Admaston
Sabine
Radcliffe
Combermere
McNab
ARNPRIOR
Bangor
Dacre
Bagot
Wicklow
Griffith
Brougham
Pakenham
McClure
Maynooth
Raglan
Lyndoch
Madawaska
Blithfield
Darling
Ramsay
Herschel
Monteagle
Carlow
Denbigh
Matawatchan
North Canonto

LOCATION MAP Scale: 1:1 548 000 or 1 inch to 25 miles

Ministry of Natural Resources, Eastern Region
In Preparation: Mineral Aggregate Resource Inventory
for the County of Renfrew.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15′
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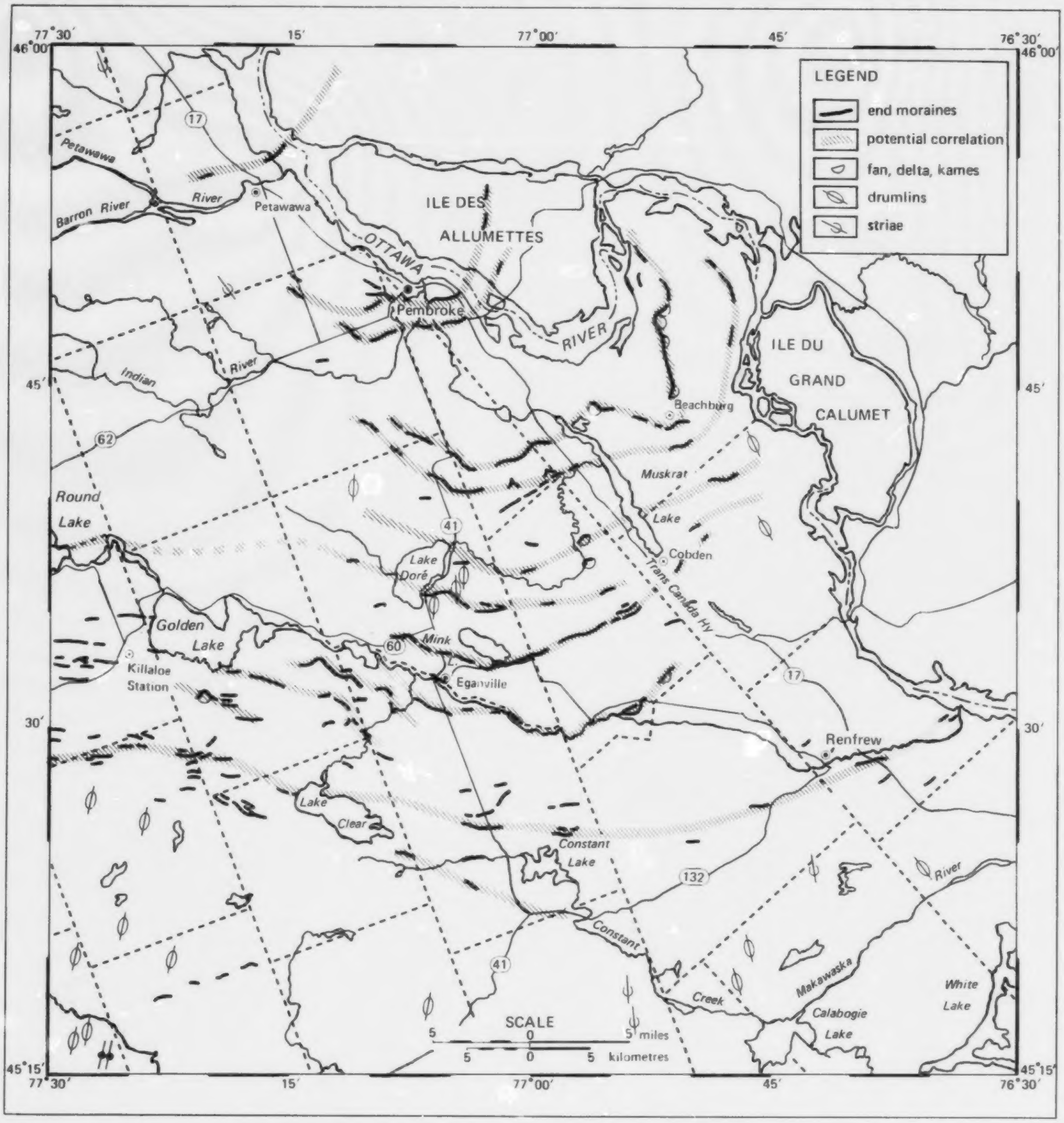
LEGEND
extent of Champlain Sea
proglacial pondings
drainage pathways
ILE DES ALLUMETTES
ILE DU GRAND CALUMET
OTTAWA RIVER
Petawawa River
Petawawa
Barron River
Pembroke
Indian River
Round Lake
Beachburg
Muskrat Lake
Cobden
Trans Canada Hy.
Killaloe Station
Mink L.
Eganville
Renfrew
Constant Lake
Constant Creek
Madawaska River
Calabogie Lake
White Lake
17
62
41
60
132
SCALE
5 0 5 miles
5 0 5 kilometres

Figure 1. The extent of the Champlain Sea and of other proglacial pondings. (Project 27.)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LEGEND
end moraines
potential correlation
fan, delta, kames
drumlins
striae
Petawawa
River
Barron River
Petawawa
17
ILE DES
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OTTAWA
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Pembroke
ILE DU
GRAND
CALUMET
Indian
River
Beachburg
62
Muskrat
Lake
Round
Lake
41
Lake
Doré
Cobden
Trans Canada Hy
Golden
Lake
Killaloe
Station
60
Mink
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Renfrew
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41
SCALE
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Figure 2. Ice-marginal positions and ice-flow directional indicators. (Project 27.)

28. Quaternary Geology of the Brampton Area, Southern Ontario

P.F. Karrow

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INTRODUCTION

The present mapping project in the Brampton area was begun in 1984 (Karrow 1984). The area covered in that year consisted of a strip several kilometres wide along the west edge of the map sheet, generally covering the area west of the Niagara Escarpment, and small areas of the adjacent till plain east of the Escarpment.

The area mapped in 1985 includes the rest of Halton Hills region, except for the urban area of Georgetown, and a small area in northwestern Peel region, east of Terra Cotta. Most of the newly mapped area is part of the extensive Halton Till Plain.

Most of the area mapped this year is underlain by red mudstone of the Ordovician Queenston Formation. Outcrops in cliffs up to 10 m high occur along Sixteen Mile Creek (Oakville Creek) near the south edge of the area east of Milton, along the Credit River north of Georgetown, and the Credit River West Branch west of Norval. More extensive outcrops occur west of Georgetown, and between Terra Cotta and Cheltenham, west of the Credit River. Outcrops of the overlying Whirlpool Formation (sandstone) of Silurian age were encountered in valleys east of Speyside.

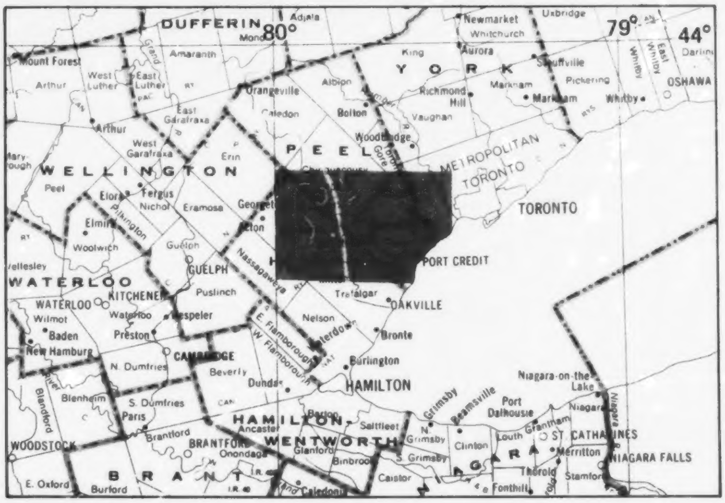
QUATERNARY DEPOSITS

The oldest deposits occur in the valley walls of the Credit River and its tributaries near Georgetown. They mainly consist of thick sequences of fine sand and fine to medium outwash sand and gravel. The sedimentology of some of these deposits was studied by Costello and Walker (1972) who described braided stream deposition with southwesterly paleoflow directions. Near Cheltenham, at the north edge of the area, laminated lacustrine clay and silt underlie or replace the glaciofluvial deposits. Lacustrine clay also occurs in this position at Georgetown. Numerous exposures indicate a substantial areal extent for these deposits below the till east of the Niagara Escarpment. How far east they extend is not known.

The Halton Till is the most extensive surface deposit in the area mapped. Typically, it is a gritty silt or clayey silt till with chips of red Queenston shale scattered through it. It is commonly brown or red-brown in colour from the effect of incorporated red Queenston shale. Other variations in texture occur, from silty clay to sandy silt, and in colour from grey to olive. Several layers of till 3 to 6 m thick occur along the Credit River near Georgetown, but all are believed to represent local fluctuations of the Halton ice.

Halton Till overlies bedrock or the water-laid deposits described above, and is believed to be of Port Huron age (about 13 000 years old). It forms a nearly level, undulating, or rolling till plain with some flutings and elongate streamline forms parallel to an ice flow direction westward to northwestward, out of the Lake Ontario basin.

A few small ice-contact deposits of fine sand and gravel occur along an east-west trend from Streetsville to Speyside. These deposits are believed to rest on the Halton Till and were presumably formed during the last retreat of the Halton ice. Outwash sand was deposited in three areas: southwest of Stewarttown, northeast of Glen Williams, and southeast of Norval. These areas are favoured for plant nurseries, market gardening, and orchards. Outwash gravel along the Credit River north of Georgetown is probably older material exposed by removal of the


DUFFERIN
80°
79°
44°
Mount Forest
Arthur
West Luther
East Luther
Amaranth
Orangeville
Albion
Bolton
Caledon
East Garafraxa
West Garafraxa
Erin
Newmarket
Whitchurch
Uxbridge
King
Aurora
YORK
Stouffville
Markham
Pickering
Richmond Hill
Vaughan
Whitby
OSHAWA
Woodbridge
PEEL
METROPOLITAN TORONTO
TORONTO
WELLINGTON
Peel
Elora
Fergus
Nichol
Eramosa
Elmira
Pilkington
Woolwich
Guelph
GUELPH
Georgetown
Milton
Nassagaweya
PORT CREDIT
Wellesley
WATERLOO
KITCHENER
WATERLOO
Wilmot
Waterloo
Hespeler
Puslinch
Trafalgar
OAKVILLE
Nelson
Bronte
Baden
New Hamburg
Preston
CAMBRIDGE
N. Dumfries
Beverly
E. Flamborough
W. Flamborough
Burlington
Dundas
HAMILTON
Blandford
Blenheim
S. Dumfries
Paris
Brantford
BRANTFORD
Onondaga
Ancaster
HAMILTON-WENTWORTH
Glanford
Binbrook
Saltfleet
Grimsby
Beamsville
N. Grimsby
S. Grimsby
Caistor
Clinton
Louth
Port Dalhousie
Grantham
Niagara-on-the-Lake
Niagara
ST. CATHARINES
Merritton
Thorold
Stamford
NIAGARA FALLS
Fonthill
NIAGARA
WOODSTOCK
E. Oxford
Burford
BRANT
Caledonia

LOCATION MAP

Scale : 1 : 1 548 000 or 1 inch to 25 miles

overlying Halton Till, but in part may be post-Halton outwash. Reworking and intermixing probably took place.

A low, broad basin east of Milton was the focus for lacustrine sedimentation during ice retreat. Deposits are commonly 1 to 2 m thick, and consist of massive to banded clay and silt, with varying amounts of glacial debris (grits, pebbles) often giving rise to till-like sediments. These are believed to originate through the action of floating ice. Because of the gentle relief of this area, the thin lake sediments are often penetrated by gentle knolls of till, and boundaries are very irregular and difficult to define. This basin is bounded on the east by the Trafalgar Moraine (Chapman and Putnam 1984), and to the north and west by higher parts of the till plain.

Numerous small pockets of lake or pond sediments are scattered across the Halton Till Plain. North of Glen Williams they occur in depressions along the trend of the Cheltenham Moraine (Taylor 1913; White 1975).

The lake sediments are attributed to a short-lived Lake Peel, which formed between the eastward retreating Halton ice and higher ground to the northwest. Its numerous levels have generally only been recognized by the presence of small deltaic sand deposits formed by streams emptying into it (Karrow 1970), although White (1975) reported some faint shorelines in the Bolton area. In the present area a deltaic sand deposit has two extensions along the flanks of the valley of Sixteen Mile Creek, southeast of Hornby, which are believed to represent beaches at about 189 m elevation. The eastern arm is the more prominent, and the undulating surface suggests some eolian reworking of the beach sands. The clays of the lagoon behind (east of) this beach bar are particularly clean and free of coarser sediment.

Terrace deposits intermediate between higher outwash levels and modern floodplain are grouped as older alluvium, and consist of sand and gravel. They are not extensive but have been recognized in the Sixteen Mile Creek valley near Milton, and more extensively along the Credit River between Terra Cotta and Norval. Modern alluvium, consisting of varied gravels, sands, and silts with organic matter, occurs on modern floodplains and along most streams. Organic deposits of peat and muck are present, but minor in extent.

ECONOMIC GEOLOGY

The chief source of sand and gravel in the mapped area is the sub-till sand and gravel along the Credit River near Georgetown. A concentration of pits, many inactive or abandoned, is located where overlying till has been stripped off by erosion. Present indications are that these deposits may be sheet-like, and have substantial areal extent below the Halton Till, although concentration along present valley trends is also possible. An inlier of sand projects through the till east of Speyside and is the site of a pit.

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29. Quaternary Geology of the Hemlo Region, District of Thunder Bay

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[2]Graduate Student, Department of Earth Sciences, University of Waterloo, Waterloo, Ontario.

[3]Geologist, Thunder Bay Mining Division, Ministry of Northern Affairs and Mines.

INTRODUCTION

Quaternary mapping of the Hemlo region continued during the summer of 1985. The central portion of the area was mapped in 1984 (Geddes and Bajc 1985a, 1985b), whereas the 1985 program included the surrounding map sheets of Marathon (NTS 42 D/9), Manitouwadge (NTS 42 F/4), and White River (NTS 42 C/11). The geographic relationships and mapping responsibilities for this project are shown in Figure 1. The total region forms an inverted "T" centred around the exploration and development activities associated with the Hemlo gold discovery.

The area is traversed by Highway 17 which forms the main east-west corridor, and Highway 614, which forms the main north-south corridor. Bush trails and forest access roads provided excellent road access in the Manitouwadge and White River areas, while water access was utilized for much of the Marathon area.

Previous Quaternary geology investigations were primarily of a reconnaissance nature (Boissonneau 1965; Zoltai 1965). The area was also covered by the engineering and terrain geology studies of Gartner and McQuay (1979, 1980). Other recent work in the area included investigations in the Marathon area by Cowan (1976), planning projects in the municipal areas by F.J. Kristjansson (unpublished reports), and field work associated with a recent aggregate resources inventory (Ontario Geological Survey, 1985). The results of the 1984 mapping program has been reported (Geddes and Bajc 1985a, 1985b), thus only the 1985 program will be summarized here.

BEDROCK GEOLOGY

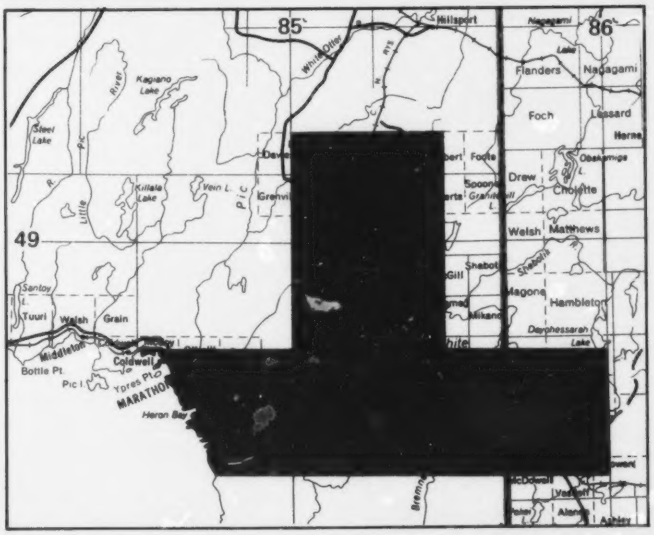
The Hemlo region has become the focus of much attention because of the recently discovered "world-class" gold deposits and associated mine development. The mineral exploration history of the area has been outlined by Patterson (1984). The geologic setting has been summarized by Muir (1983).

For the 3 areas mapped in 1985, the relevant geologic studies are as follows: for Marathon, Muir (1982a, 1982b), for Manitouwadge, Pye (1960) and Milne (1968), and for White River, Fenwick (1967) and Siragusa (1985).

QUATERNARY GEOLOGY

The direction of the last (Late Wisconsinan) glacial advance over the region shows a consistent trend of about 210° azimuth in the northern areas. In the southern portions, the ice flow exhibited a more radial trend. In both the Marathon and White River areas, glacial striae reveal an early north to south direction, followed by a well developed dominant ice direction which varies from 220° azimuth in the east to 250° azimuth in the west, along the shores of Lake Superior.

The thickness of glacial drift in the region is quite variable. Much of the area investigated in 1985 is covered by only a thin veneer of overburden. Rock outcrop is particularly common in the south-central part of the Marathon area and in the north-central portion of the White River area. Elsewhere, drift thick-


85°
86°
49
Hillsport
Nagagami
Lake
Flanders
Nagagami
Foch
Lessard
Herne
White Otter
RYS
Kagiano Lake
River
Steel Lake
Pic
R.
Little
Killala Lake
Vein L.
Pic
Grenvil
Dave
bert
Foote
Spoon
Granite
L.
Drew
Obakamiga L.
Cholette
Welsh
Matthews
Shabotik
Shebot
Gill
Magone
Hambleton
Dayohessarah Lake
Mikano
hite
Santoy L.
Tuuri
Walsh
Grain
Middleton
Coldwell
Bottle Pt.
Pic I.
Ypres Pt.
MARATHON
Heron Bay
Bremner
McDowell
Vasiloff
Alona
Ashley

LOCATION MAP Scale : 1 : 1 584 000 or 1 inch to 25 miles

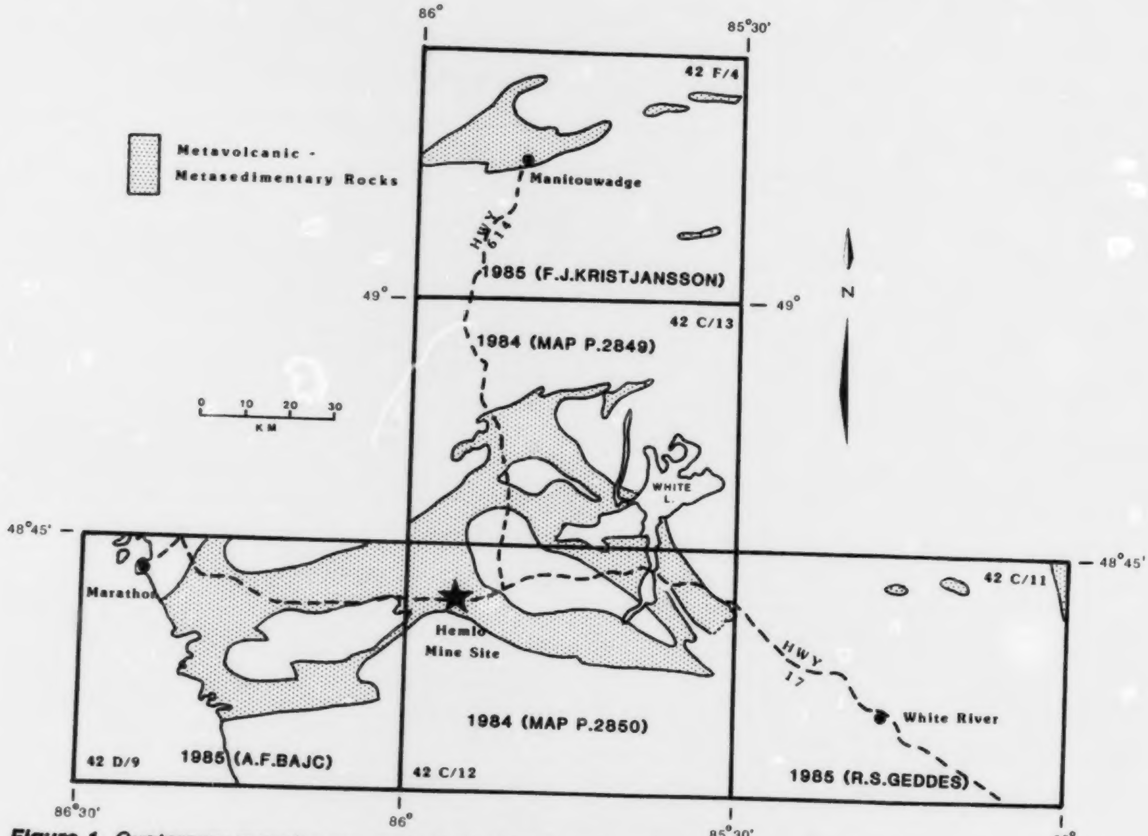


Figure 1. Quaternary mapping programs in the Hemlo region, 1984 to 1985. (Project 29.)

ness can exceed 100 m. Particularly extreme variations in overburden thicknesses are common in the Marathon area.

Deposits of till are extensive in the Manitouwadge and White River areas, but are very sparse around Marathon. Rocky upland areas are generally covered with a veneer of stony, sandy till of relatively local derivation. Several exposures in the Manitouwadge and White River areas reveal that a carbonate-rich, silty to silty sand till is prominent in areas of thicker till cover. The till sequence in these areas is consistent with that reported previously (Geddes and Bajc 1985a, 1985b), and consists of both very dense and loose facies of calcareous till. This sequence is periodically capped by a sandier, non-calcareous and more locally derived till variety. The dense calcareous phase is quite common in the White River area, while the looser phase is prominent in the Manitouwadge area.

There are two major types of glaciofluvial ice-contact deposits within the 1985 project area. In the White River map area there are three very similar esker-kame complexes which transect the region in a south-southwesterly orientation. In the vicinity of the town of Marathon, there is a prominent ice-proximal deltaic feature which was heavily pitted by remnant ice masses. Some of these kettle depressions are up to 80 m deep. Glaciofluvial deposits in the Manitouwadge area are much less common, consisting of scattered esker, kame, and kame-delta sequences.

Major outwash sequences occur within drainage channels in the easternmost part of the Manitouwadge map area, and along the northern edge of the White River area. The latter eventually joins a major system which occupies much of the White River valley.

Glaciolacustrine deposits are common in the western portion of the region, and, along with deltaic deposits, comprise about half of the Marathon area. The sedimentary sequences often consist of thick, varved clay and silts, overlain by shallow lacustrine and fluvio-deltaic sands. These deposits are continuous northward, occupying the major river valley areas along the western portion of the Manitouwadge map area.

Beach and near-shore deposits are extensive in the Marathon area. Associated wave-cut bluffs, beach ridges, and near-shore bars are well developed near the Lake Superior shoreline.

Eolian deposits, consisting predominantly of sand dunes, are scattered over the region, being confined to broad glaciolacustrine and outwash plains. These deposits are best developed and exposed within the Marathon map area, specifically at the mouth of the Pic River and along Highway 17.

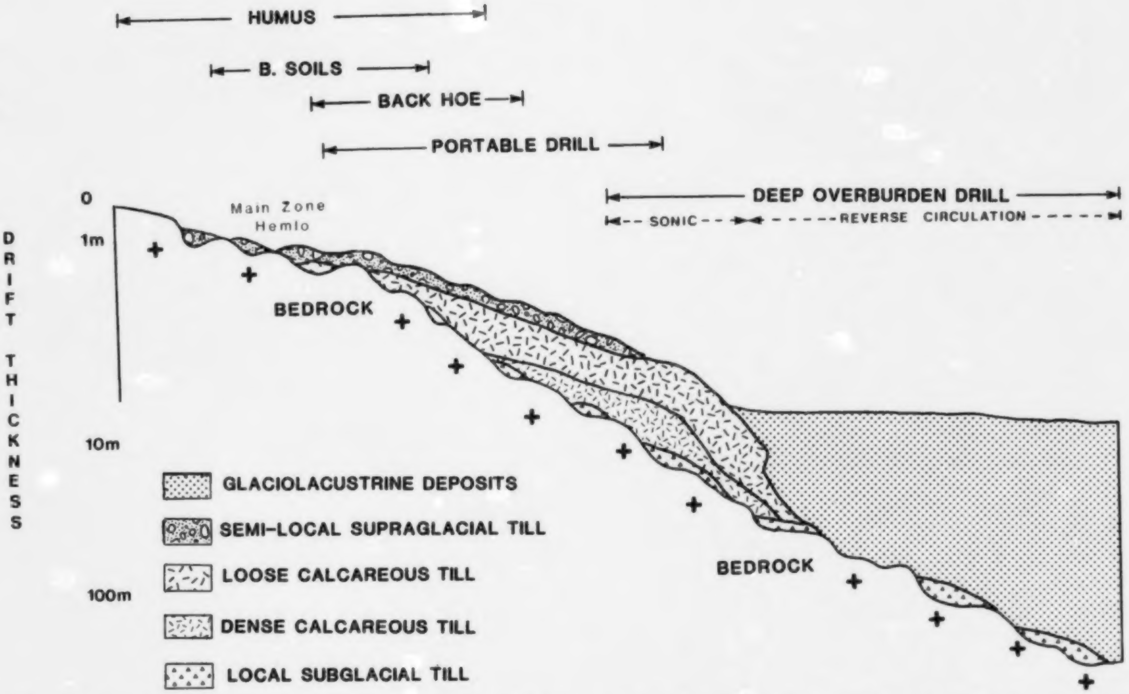


Figure 2. *A summary of Quaternary deposits of the Hemlo region and associated limitations of the surficial exploration techniques (Geddes and Kristjansson 1984). (Project 29.)*

Older alluvium is also well developed within the Marathon map area. The deposits range from pebbly sands to clayey silts. Five distinct terraces, related to the changing Holocene lake levels of the Superior basin, have been recognized.

APPLIED QUATERNARY GEOLOGY

There are several applied benefits which can be derived from an understanding of the Quaternary geology of the Hemlo region. Two important aspects involve the aggregate resources required for the mining and associated municipal developments, and the effects and constraints on further gold exploration in the area, using drift prospecting techniques.

Results of the mapping program have been incorporated in a detailed account of the aggregate resources of the Hemlo area (Ontario Geological Survey 1985). This study has outlined six areas of primary significance within a 20 km radius of the mining camp, and 8 primary aggregate sources within the municipalities of Marathon, Manitouwadge, and White River. The majority of the best quality aggregate is contained within major glaciofluvial features. Other aggregate and fill materials are also available from a wide range of glacial deposits.

The Quaternary cover also exerts considerable control on the effectiveness of surficial gold exploration techniques (Geddes and Kristjansson 1984). For example, the thick and variable glaciolacustrine deposits of the Marathon area provides a distinct impediment to various exploration techniques over very highly prospective ground (e.g. Heron Bay area). The 1985 program has detailed the nature and distribution of these and associated sediments, and will provide necessary data for incorporation in any exploration approach in this area. Similarly, the non-local, carbonate-rich till elsewhere in the region, has considerable effect on till sampling methods and related exploration models (Gleeson and Sheehan 1984). A general summary of the Quaternary deposits and stratigraphy, and associated limitations on surficial exploration techniques is provided in Figure 2.

RELATED RESEARCH

A. Bajc is completing an M.Sc. thesis on the glaciolacustrine environments and associated fauna of the area, at the University of Waterloo. Professor S.R. Hicock, University of Western Ontario, has commenced detailed studies of the depositional processes of the carbonate-rich till with a grant from the Ontario Geoscience Research Fund. Also, at the same university, Elizabeth Woods completed a B.Sc. thesis relating surficial geology to lakewater alkalinity in the Hemlo area, and Thomas N. White has commenced a B.Sc. thesis on till genesis in the White River area.

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S30. Paleozoic Geology of Cockburn Island, District of Manitoulin

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INTRODUCTION

Geological mapping and sampling of the Paleozoic rocks on Cockburn Island, District of Manitoulin, was conducted during the 1985 summer field season. A stratigraphic test drillhole completed in late September, 1985, provided additional geological information.

The study area lies within the west half of the 1:50 000 Meldrum Bay (NTS 41 G/14) topographic map sheet. Located between Lake Huron and the North Channel, Cockburn Island is separated from Manitoulin Island to the east by Mississagi Strait, whereas False Detour Channel to the west separates Cockburn Island from Drummond Island, Michigan, U.S.A. Cockburn Island is bounded approximately by Latitude 46°00′N and 45°50′N, and by Longitude 83°30′W and 83°15′W.

This project was made possible through in-year supplementary funding by the Government of Ontario.

GENERAL GEOLOGY

Sparse outcrops of Paleozoic carbonate rocks occur in the northern half of Cockburn Island. Thick Quaternary deposits cover most of the island, especially the central and southern parts. The formations which outcrop on the island (Table 1) are Middle Silurian in age.

TABLE 1. PALEOZOIC STRATIGRAPHY OF OUTCROPS ON COCKBURN ISLAND

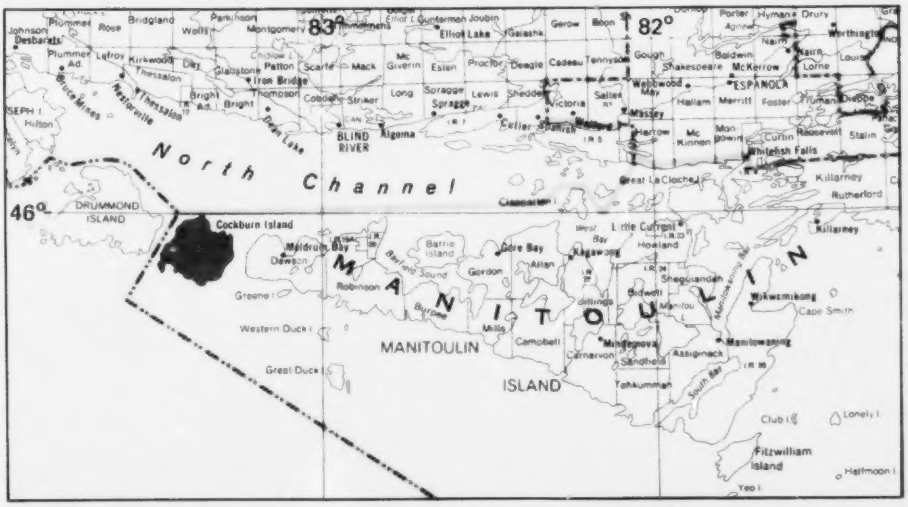
MIDDLE SILURIAN
- Amabel Formation
- Fossil Hill Formation
- St. Edmund Formation
- Wingfield Formation
- Dyer Bay Formation

Previous geological studies on Cockburn Island were done by Williams (1919), Kelley (1949), and Liberty (mapped in 1954 to 1957, published in 1972). This project follows the stratigraphic nomenclature for the Middle Silurian used by Johnson and Telford (1985).

The oldest exposed unit on Cockburn Island is the Dyer Bay Formation, which consists of blue-grey, thinly bedded, medium crystalline dolostone. A thick horizon near the base of the formation is very fossiliferous with the pentamerid brachiopod *Virgiana*.

Overlying the Dyer Bay Formation is the Wingfield Formation, which on Manitoulin Island is an interbedded dolostone and shale (Johnson and Telford 1985). On Cockburn Island no outcrops of the Wingfield Formation were identified.

The St. Edmund Formation, as redefined by Johnson and Telford (1985), outcrops along the northwestern and northeastern corners of the island. Conformably overlying the Wingfield Formation, the St. Edmund Formation consists of pale grey, thinly bedded, lithographic to sublithographic, occasionally laminated dolostone alternating with beds of brown, medium bedded, medium to coarsely crystalline dolostone. The coarser crystalline beds predominate in the basal portion of the formation, whereas lithographic beds are more common in the upper part. In the northwestern corner of Cockburn Island, the brown, medium to coarsely crystalline dolostone has been altered by extensive silicification, which produces a distinctive vuggy texture. In the same area, this formation also contains a 2 m thick interval of pale grey, lithographic limestone, possibly correlative with the Fiborn Limestone Member of the Hendricks Dolomite, Drummond Island, Michigan (Johnson and Sorensen 1978).



LOCATION MAP

Scale: 1:1 548 000 or 1 inch to 25 miles

Disconformably overlying the St. Edmund Formation, is the Fossil Hill Formation, a buff to grey-brown, thinly to thickly bedded, finely to coarsely crystalline dolostone. Near the base of this formation is a 3 to 4 m thick bed of lithographic dolostone, similar to the upper part of the St. Edmund Formation. Soft, white chert is also abundant in horizons near the top of the Fossil Hill Formation. This formation is highly fossiliferous, especially in corals, stromatoporoids, and pentamerid brachiopods.

The Amabel Formation, the youngest and most areally extensive formation in the study area, disconformably overlies the Fossil Hill Formation. Outcrops of the Amabel Formation on Cockburn Island consist of white to blue-grey, massive to thickly bedded, medium crystalline dolostone (Facies III of Johnson and Telford 1985). Occasionally, thin horizons of pentamerid brachiopods were identified.

The total thickness of exposed Paleozoic rocks on Cockburn Island is about 65 m.

Most of Cockburn Island is covered by thick, extensive Quaternary deposits. The central portion of the island is dominated by a 70 m hill of morainic debris which has been superficially reworked by glacial lakes. The northern part of the island is covered by cobble and boulder beaches near the present day shoreline, and by extensive wave-cut terraces with boulder pavements further inland. The southern part of the island is covered by extensive sandy beach berms and occasional boulder pavements. Recent organic swamp deposits cover a significant part of the southwestern portion of the island.

COCKBURN ISLAND DRILLHOLE

To supplement the outcrop data, a deep stratigraphic test drillhole was cored on Cockburn Island. The drillhole was located on lot 16, concession II, Township of Cockburn Island. A high recovery rate was obtained, with a continuous core of NQ size (4.5 cm diameter) being recovered to a total depth of 521 m. A continuous section from the Middle Silurian Amabel Formation down to about 30 m into the Precambrian was obtained. Additional lithological description of the core will be published as an Open File Report.

ECONOMIC GEOLOGY

One small abandoned quarry near the village of Cockburn Island was worked for a short time, near the turn of the century, to obtain rock for use in a sulphite-pulp mill (Goudge 1938). Three petroleum exploration wells, drilled to the Precambrian during 1936-1937, were unsuccessful in locating commercial oil or gas deposits. Several small gravel pits are used for aggregate on local roads.

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31. Aggregate Resources Inventory in Southwestern Ontario

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INTRODUCTION

Field work was conducted in southwestern Ontario during the 1985 field season as part of the Aggregate Resources Inventory Program. The results of the various field activities will be published in Aggregate Resources Inventory Papers or released in Open File Reports as applicable. The areas involved in field investigations were:

1. Kent and Middlesex Counties
2. Huron and Perth Counties
3. Bruce County

Field investigations consisted of the following activities: examination of potential aggregate deposits, existing pits and quarries, natural and man-made exposures, as well as auger drilling. All active and abandoned pits were investigated and at each site several observations were made, including: face height, percentage of gravel and sand, and the presence of deleterious materials such as chert, shale, clay, silt, and oversized boulders. The intended uses of the granular material and the presence of stockpiles, water-filled ponds, crushing plant, and rehabilitation work were also noted. Estimates were made of the amount of material previously extracted from these pits to enable resource tonnage evaluations to be determined. Active and abandoned quarries were also visited. At these sites, the height of the quarry face was noted, as well as bedrock geology, and the presence of deleterious materials.

The purpose of the field investigations was to confirm and supplement the information gathered from various sources such as existing geological reports and maps, data from the files of the Ontario Ministry of Transportation and Communications, and water well data from the Ontario Ministry of the Environment. In areas where pre-existing data were unavailable or insufficient, representative channel face samples were taken from exposed faces. These samples have been sent to the Ontario Ministry of Transportation and Communications to be analyzed for grain size distribution, soundness, absorption, and lithology (petrographic number or P.N.).

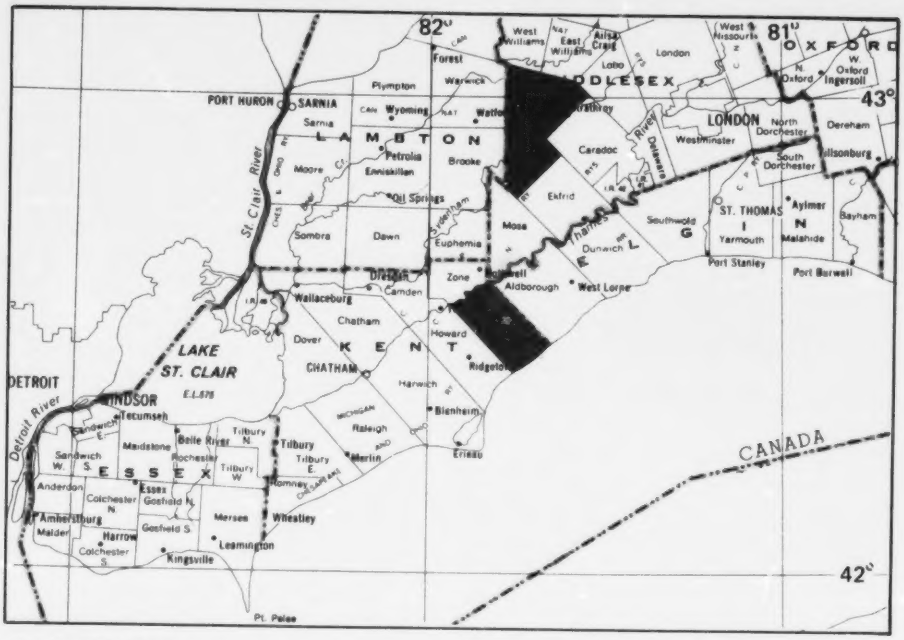
KENT AND MIDDLESEX COUNTIES

The aggregate potential of Orford Township in southeastern Kent County was investigated. The predominant aggregate-bearing glacial sediments in the township are the raised shoreline features located on the edges of the Blenheim Moraine where glacial Lakes Warren, Arkona, and Whittlesey once stood. Extraction has been centred in a large beach deposit extending from Highgate to Clachan. Generally, pit faces in this deposit expose fair to poor quality, poorly sorted, fine aggregate. The use of the material is severely limited because it contains a large percentage of deleterious materials such as shale and chert. Deposits of glaciofluvial outwash sand and minor gravel located along the Thames River valley and south of Duart, are expected to contain material suitable for low specification uses. A thin and discontinuous veneer of fine to medium aeolian sand which comprises part of the Bothwell sand plain north of the Blenheim Moraine contains material suitable for fill. Devonian shales and limestones of the Hamilton Group and Kettle Point Formations underlie Orford Township. Both formations are unsuitable for aggregate use and are thickly drift covered.

Adelaide and Metcalfe Townships in west-central Middlesex County were also investigated. Licensed pits have been established in poorly sorted ice-contact sediments, located north of the Seaforth Moraine in Adelaide Township. Deposits in this area contain predominantly fine aggregate. Although some of the ice-contact deposits contain isolated pockets of slightly higher gravel content, quantities of good quality crushable gravel are lacking in both townships. Despite the quality and quantity limitations, the ice-contact deposits should be regarded as important local sources of sand and gravel. Minor resources of sand and gravel were also located in a succession of raised shorelines deposited at the margins of several former glacial lakes. Extensive deposits of fine to medium aeolian sand derived from the sediments of the Coldstream-Poplar Hill delta are located in the Strathroy area (Cooper *et al.* 1978). The underlying Devonian bedrock is not a viable aggregate resource as it is deeply buried and unsuitable for aggregate uses.

PERTH COUNTY

Field investigations were conducted in Hibbert and Wallace Townships in Perth County. The most significant sand and gravel deposits in both townships were formed as the Huron and Georgian Bay lobes disappeared from the areas. The most prominent gravel-bearing deposit in Hibbert Township is the Staffa kame complex, located between the Dublin and Lucan Moraines. The kame complex has been a traditional supplier of good-quality crushable gravel suitable for a wide range of aggregate products. Sand and gravel has also been found in minor kame deposits, outwash deposits, and within the Mitchell esker, which were all formed when the margin of the Huron lobe retreated from Hibbert Township. The township is underlain by bedrock of the Dundee and Detroit River Group strata. Although some of the strata is suitable for the production of construction aggregate, excessive drift covers much of the township with the exception of an area near Cromarty. A small building stone quarry located near Cromarty was investigated during the field season.


82°
81°
43°
42°
PORT HURON
SARNIA
LAMBTON
MIDDLESEX
OXFORD
LONDON
ELGIN
KENT
ESSEX
ST. THOMAS
CHATHAM
LAKE ST. CLAIR
DETROIT
WINDSOR
CANADA
St. Clair River
Detroit River
Thames River
Forest
Plympton
Warwick
Sarnia
Wyoming
Petrolia
Moore
Enniskillen
Brooke
Oil Springs
Sombra
Dawn
Euphemia
Dresden
Camden
Wallaceburg
Chatham
Dover
Howard
Zone
Ridgetown
Harwich
Blenheim
Raleigh
Merlin
Erieau
Tilbury
Tilbury N.
Tilbury E.
Tilbury W.
Romney
Wheatley
Mersea
Leamington
Kingsville
Gosfield N.
Gosfield S.
Essex
Belle River
Rochester
Maidstone
Tecumseh
Sandwich E.
Sandwich W.
Sandwich S.
Anderdon
Amherstburg
Malden
Colchester N.
Colchester S.
Harrow
Pt. Pelee
West Williams
East Williams
Ailsa Craig
Lobo
London
Strathroy
Caradoc
Ekfrid
Mosa
Aldborough
West Lorne
Dunwich
Southwold
Yarmouth
Port Stanley
Westminster
North Dorchester
South Dorchester
Aylmer
Malahide
Bayham
Port Burwell
Dereham
Tillsonburg
West Nissouri
N. Oxford
W. Oxford
Ingersoll
Wardsville

LOCATION MAP

Scale : 1 : 1 584 000 or 1 inch to 25 miles

Further assessment of Wallace Township was completed in 1985. The chief sources of sand and gravel are concentrated within the numerous interconnecting meltwater channels located along the Maitland River Valley, and in small ice-contact stratified drift and esker deposits. The quality of the gravel in the township is poor because of the presence of a high percentage of deleterious materials such as chert and highly absorptive limestone derived from the Salina, Bertie, and Bois Blanc Formations (Deike 1982). The presence of these lithologies in the material limits its use in high specification aggregate products such as structural concrete or hot-laid paving mixes. The bedrock formations underlying Wallace Township are unsuitable for aggregate use and are covered by excessive drift.

HURON COUNTY

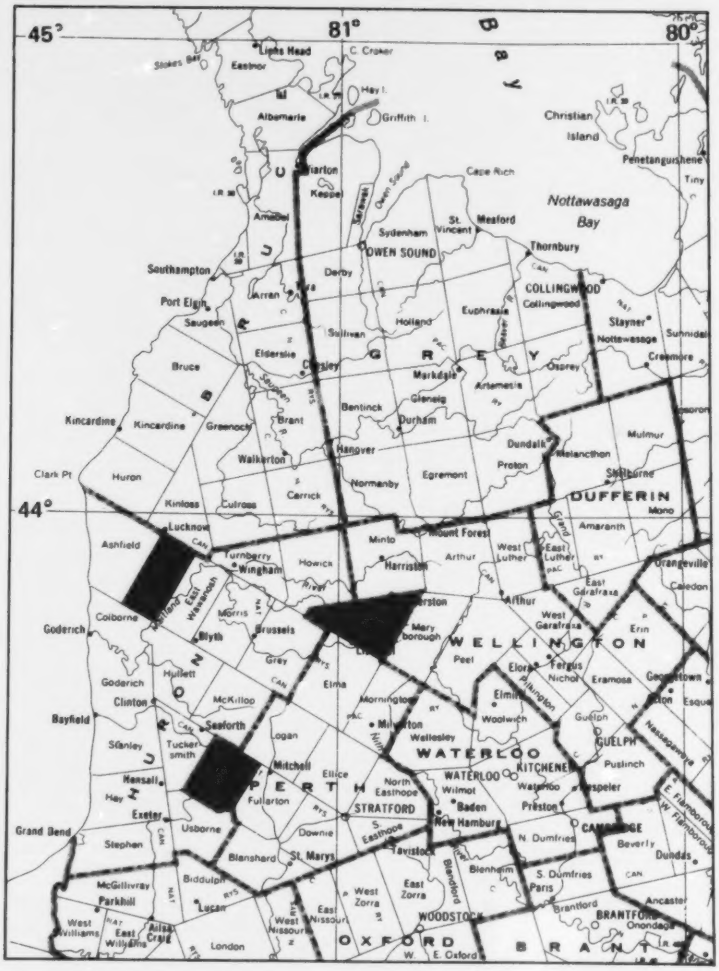
Much of West Wawanosh Township is dominated by the high relief and hummocky topography of the Wawanosh Moraine. Formed by the interaction of the Huron and Georgian Bay lobes, the moraine contains resources of ice-contact stratified drift, and extensive amounts of glacial till in some areas. Substantial deposits of good-quality crushable outwash gravel are located along the Maitland and Lucknow Rivers and Sharpes Creek. These deposits were formed by the drainage of meltwaters flowing off the Georgian Bay and Huron lobes during deglaciation, and represent significant resource areas. Large scale extractive operations have been established in these deposits and are capable of supplying a wide range of aggregate products. Thick drift prevents any of the underlying Devonian strata from being mined.

BRUCE COUNTY

Detailed field investigation of Amabel Township in central Bruce County revealed that the Township contains locally significant reserves of surficial sand and gravel.

The sand and gravel resources are concentrated in a number of scattered ice-contact stratified drift and esker deposits as well as in numerous glaciolacustrine beach and plain deposits. The ice-contact stratified drift deposits include kame-like mounds found in association with small eskers which were deposited during deglaciation of the Georgian Bay lobe (Sharpe and Jamieson 1982). These deposits are generally thin and contain poorly sorted fine gravel with a medium to coarse grained sand matrix. The coarser glaciolacustrine deposits were derived from the local till by the repeated wave action of the waters of glacial Lakes Algonquin and Nipissing. These lakes formed very well developed wave-cut bluffs in the township. The beach deposits are numerous and contain a high percentage of subrounded to well rounded, moderate to well sorted, fine to coarse grained gravel in a matrix of often silty to clayey medium grained sand. Sand and gravel derived from these deposits has been utilized for a wide range of road-building and construction products. Large amounts of fine to medium sand suitable for fill occur in an extensive aeolian deposit that parallels the present Lake Huron shoreline.

Much of the northern portion of Amabel Township is covered by thin drift with extensive bedrock exposures consisting of dolostone of the Amabel and Guelph Formations. At the time of field checking, there were five licensed quarries mining the dolostone of the Eramosa Member (Amabel Formation) to produce coursing stone, flagstone, sills, steps, and other ornamental stone. The bituminous


45°
81°
80°
Bay
Lions Head
Eastnor
Stokes Bay
Albemarle
C. Croker
Hay I.
Griffith I.
Christian Island
Wiarton
Keppel
Amabel
Cape Rich
Nottawasaga Bay
Penetanguishene
Tiny
Sydenham
St. Vincent
Meaford
Thornbury
OWEN SOUND
Owen Sound
Sarawak
Southampton
Derby
Port Elgin
Arran
Saugeen
COLLINGWOOD
Collingwood
Stayner
Nottawasaga
Sunnidale
Holland
Euphrasia
Sullivan
Elderslie
Chesley
Osprey
Creemore
Bruce
G R E Y
Markdale
Artemesia
Bentinck
Glenelg
Kincardine
Kincardine
Greenock
Brant
Durham
Dundalk
Melancthon
Mulmur
Hanover
Walkerton
Proton
Clark Pt
Huron
Carrick
Normanby
Egremont
Shelburne
DUFFERIN
Mono
44°
Kinloss
Culross
Lucknow
Mount Forest
Amaranth
Ashfield
Turnberry
Wingham
Howick
Minto
Arthur
West Luther
East Luther
Harriston
Orangeville
East Garafraxa
Caledon
Palmerston
Arthur
Colborne
West Wawanosh
East Wawanosh
Morris
Maryborough
Goderich
Blyth
Brussels
West Garafraxa
Erin
W E L L I N G T O N
Goderich
Hullett
Grey
Peel
Elora
Fergus
Nichol
Eramosa
Georgetown
Acton
Esquesing
Clinton
McKillop
Elma
Listowel
Mornington
Elmira
Bayfield
Seaforth
Logan
Woolwich
Guelph
Stanley
Tuckersmith
Milverton
Wellesley
GUELPH
Mitchell
Ellice
W A T E R L O O
KITCHENER
Puslinch
Hensall
Hay
P E R T H
North Easthope
WATERLOO
Wilmot
Waterloo
Hespeler
Nassagaweya
Fullarton
STRATFORD
Baden
Preston
E. Flamborough
W. Flamborough
Exeter
Usborne
New Hamburg
CAMBRIDGE
Grand Bend
Stephen
Downie
S. Easthope
N. Dumfries
Beverly
Dundas
Blanshard
St. Marys
Tavistock
Blenheim
McGillivray
Biddulph
Blandford
S. Dumfries
Paris
Ancaster
Parkhill
Lucan
East Nissouri
West Zorra
East Zorra
Brantford
BRANTFORD
Onondaga
West Williams
East Williams
Ailsa Craig
London
West Nissouri
WOODSTOCK
O X F O R D
W. E. Oxford
B R A N T
H U R O N
B R U C E
CAN
NAT
RYS
PAC
I.R.

LOCATION MAP Scale : 1 : 1 548 000 or 1 inch to 25 miles

and shaley partings present in the dolostone allows the easy removal of the thinly bedded layers. The Eramosa Member is not well suited for aggregate production in this area because of the thin layers and shaley partings. However, the interreefal areas of the Amabel Formation are of high quality and are suitable for use in crushed stone, concrete aggregate, building stone, and as raw material for lime manufacture. Thin drift-covered areas of the Guelph Formation also hold potential for future mining. This rock formation, however, is best suited for the production of high purity dolomitic lime.

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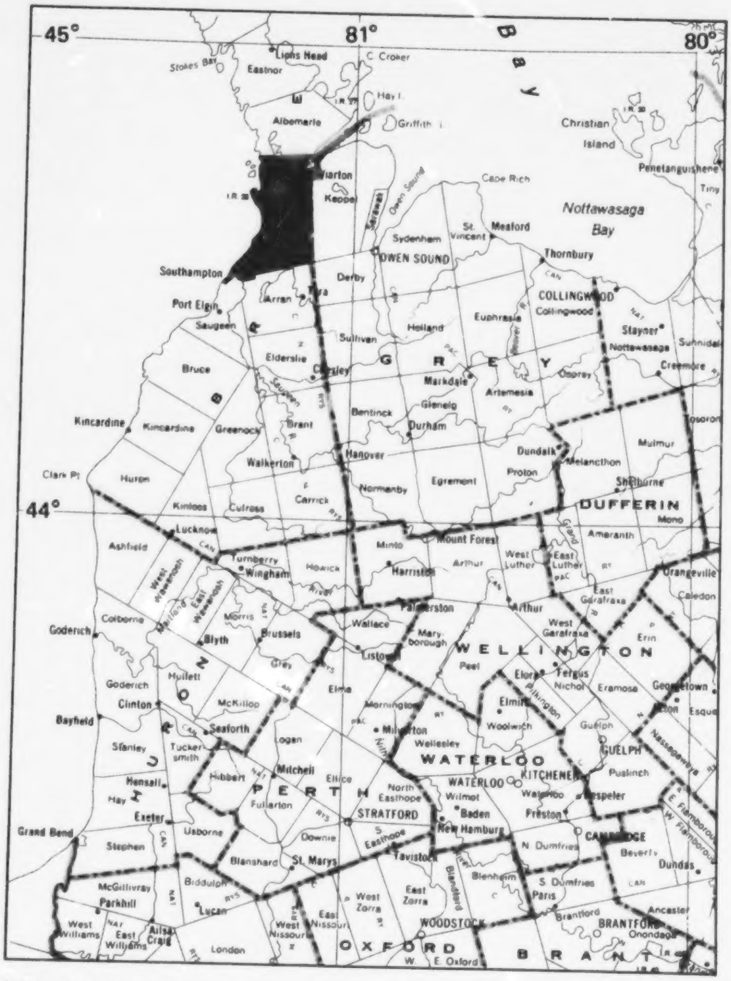

LOCATION MAP Scale : 1 : 1 548 000 or 1 inch to 25 miles

S32. Aggregate Resources Inventory Northwest of Sudbury

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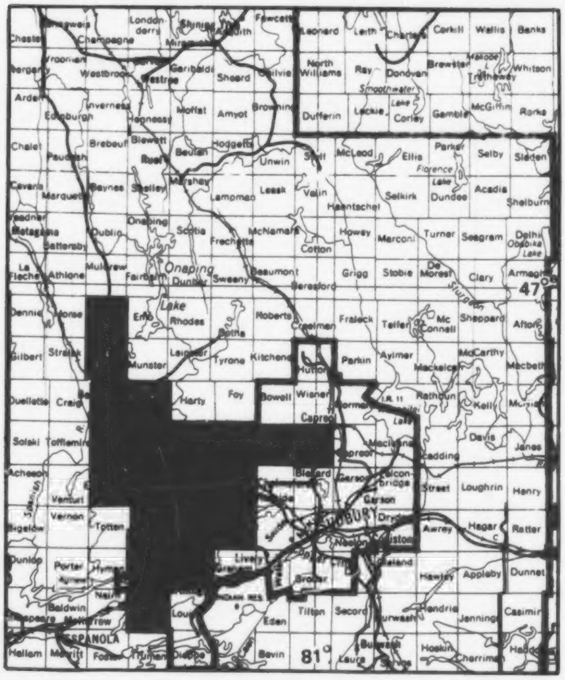
INTRODUCTION

During the 1985 field season, work was conducted in 20 townships, generally located to the northwest of the City of Sudbury, as part of the Aggregate Resources Inventory Program. The townships assessed include: Antrim, Cartier, Cascaden, Ermatinger, Hart, Hess, Moncrieff, part of Trill, and Ulster, District of Sudbury, and Balfour, Creighton, Denison, Drury, Dowling, Fairbank, Hanmer, Levack, Lorne, Lumsden, Morgan, and part of Trill, Regional Municipality of Sudbury. These townships, shown on the location map, occupy an area of approximately 2000 km^2.

The purpose of this investigation was to delineate and determine the quality and quantity of aggregate within the area to help ensure sufficient aggregate resources are available for future use. Emphasis was placed on determining aggregate quality, especially with respect to chemical reactivity, as undesirable chemical reactions have been identified as occurring in certain concrete structures built with aggregate from the Sudbury basin.

Field investigations involved the examination of potential aggregate deposits and all natural and man-made exposures. Observations made at pit sites included the estimation of face height, percentage of gravel and sand, and the presence of objectionable materials. Soil probing, hand augering, and geophysical techniques were used to assess subsurface materials in areas of limited exposure. In addition, 39 test holes were excavated using a backhoe to determine the continuity and quality of the aggregate at depth. Over 200 samples were taken for quality testing during the course of the investigation.

This project was made possible through in-year supplementary funding of the Government of Ontario.


Londonderry
Fawcett
Leonard
Leith
Corkill
Wallis
Banks
Champagne
Vrooman
Westbrook
Garibaldi
Sheard
North Williams
Ray
Donovan
Brewster
Whitson
Trethewey
Smoothwater
Lake
Arden
Inverness
Edinburgh
Hennessy
Moffat
Amyot
Dufferin
Leckie
Corley
McGiffin
Roche
Chalet
Brebeuf
Blewett
Beulah
Hoggeths
Unwin
McLeod
Ellis
Parker
Selby
Sladen
Florence
Lake
Shelley
Lampman
Leask
Valin
Selkirk
Dundee
Acadia
Marquette
Baynes
Haentschel
Onaping
Scotia
McNamara
Howey
Marconi
Turner
Seagram
Delhi
Obabika Lake
Dublin
Frechette
Cotton
Battersby
La Fleche
Athlone
Mulcrew
Fairbairn
Onaping
Dunlap
Sweeny
Beaumont
Beresford
Grigg
Stobie
De Morest
Clary
Sturgeon
47°
Lake
Rhodes
Roberts
Creelman
Fraleck
Telfer
Mc Connell
Sheppard
Afton
Gilbert
Munster
Botha
Tyrone
Kitchener
Parkin
Aylmer
McCarthy
Mackelcan
Macbeth
Ouellette
Craig
Harty
Foy
Bowell
Wisner
I.R. 11
Rathbun
Kelly
Capreol
Solski
Davis
Janes
Acheson
Street
Loughrin
Henry
Garson
Venturi
Vernon
Totten
SUDBURY
Awrey
Hagar
Ratter
Dunlop
Porter
Agnew
Nairn
Graham
Lively
Broder
Cleland
Hawley
Appleby
Dunnet
Baldwin
Tilton
Secord
Eden
Hendrie
Jennings
Casimir
ESPANOLA
Hallam
Merritt
Foster
Truman
Bevin
81°
Hoskin
Cherriman

LOCATION MAP

Scale: 1:1 584 000
or 1 inch to 25 miles

BEDROCK

The bedrock in the Sudbury area is part of the Southern Province of the Canadian Shield. The most prominent bedrock feature in the area is the Sudbury Basin. A complex group of rocks are associated with this large oval-shaped structure, including rocks of the Nickel Irruptive which contains nickel-bearing ore. Granitic rocks of early Precambrian age also underlie large parts of the study area, and a 'greenstone' belt exists north of Cartier. Rocks of the Huronian Supergroup lie northeast, south, and southwest of the Sudbury Basin. The rocks of this supergroup are the source of the sandstone, greywacke, and argillite clasts in the area's gravels which are potentially reactive with cement.

SURFICIAL GEOLOGY

A discontinuous cover of till was deposited throughout the project area by glacial ice which advanced in a south to southwesterly direction (Boissonneau 1968; Burwasser 1979). This sandy till generally exists as a thin veneer over bedrock, although in several areas significant thicknesses can be observed. The thicker till accumulations are usually associated with east-west trending moraine ridges deposited during temporary halts of the retreating ice front.

The location of the remaining glacial sediments in the area is generally restricted to bedrock controlled valleys or basins. Such is the case with the glaciofluvial deposits in the area which were deposited as the ice front retreated northwards. Two types of glaciofluvial deposits are represented in the area. Those closely associated with the ice during deposition are known as ice-contact deposits. Outwash features were deposited by meltwaters flowing beyond the ice margin.

As the ice front retreated north of the Sudbury Basin, the basin was inundated by glacial lake waters. Where glaciofluvial systems entered this lake along the rim of the basin, broad glaciolacustrine deltas were formed. In the shallow waters of the lake, reworking of the deltaic sediments by wave action resulted in the development of glaciolacustrine beach terraces. Sand, silt, and clay, which are the predominant surficial materials exposed in the basin, were deposited on the floor of this lake.

AGGREGATE DISTRIBUTION AND QUALITY

The glaciolacustrine delta and glaciofluvial deposits are the major sources of aggregate in the Sudbury area. Of these deposits, the glaciofluvial outwash features are the most widespread. The outwash largely consists of well stratified and uniformly bedded sand and gravel and has been a traditional source of aggregate in the area. Major outwash deposits are situated in the valleys presently occupied by the Spanish, Onaping, and Nelson Rivers, and Bailey, Moncrieff, John, Pumphouse, and Sandcherry Creeks (Gartner 1980a, 1980b, 1980c; Proctor and Redfern Limited 1978).

The ice-contact deposits including eskers and kames also contain locally significant resources of sand and gravel. The esker ridges rise between 10 to over 100 feet (3 to 30 m) above the surrounding terrain and trend in a general north to south, or northeast to southwest direction across the report area. Esker ridges occupy valleys throughout the area. The most prominent esker extends from Levack to Trill Township. Kames are hummocky mound-like features and are especially abundant in Drury Township.

Along the northern rim of the Sudbury Basin, significant aggregate resources are available from deltaic deposits. The deltas consist of well stratified and uniformly bedded sand and gravel. In several pits over 40 feet (12 m) of deltaic material is exposed. The deltas, located in Dowling, Morgan, Lumsden, and Hanmer Townships, are well situated with respect to local markets.

For the most part, the project area contains abundant aggregate resources. Resources are considered to be limited, however, in Balfour, Fairbank, Creighton, Denison, and Lorne Townships. Areas of concentrated pit development include Levack Township, where there exists a high demand for sand for use as mine backfill, and along the rim of the basin close to the Sudbury market.

In general, the aggregate in the area is hard and durable and suitable for a variety of road-building and general construction applications. Products from pits in the area include concrete and asphaltic aggregate, as well as granular base coarse. The aggregate usually contains only minor amounts of fines, and soft and friable clasts. An exception occurs in Drury Township where the aggregate is iron stained, cemented, and contains abundant soft and weathered clasts which would restrict high specification aggregate uses.

A major limiting factor concerning the quality of the gravel in the Sudbury area is the presence of sandstone, argillite, and greywacke clasts which are potentially chemically reactive with cement and over time can lead to concrete deterioration (Rogers 1983). Structures affected by this reaction include bridges, dams, curbs and gutters, which are subject to moist environments and/or road salts. For these reasons, the Ontario Ministry of Transportation and Communications (MTC), has placed a limit of 15% as the maximum amount of potentially reactive clasts allowed in concrete aggregate in the Sudbury area (E. Magni, personal communication, 1985). To meet this criteria, aggregate is currently being imported into the Sudbury area from the North Bay area. Preliminary results from laboratory tests on gravel samples taken during this project indicate that several deposits in the study area have potential to meet the above specification and represent relatively close-to-market sources. Detailed quality testing will be undertaken on selected samples, in the laboratories of the MTC, to assess the overall quality of the aggregate. For other structural concrete uses such as foundations and mine structures, there presently appears to be no apparent evidence of deterioration caused by this reaction.

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33. Aggregate Resources Inventory West of Espanola

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[3]Supervisor, Aggregate Assessment Office, Engineering and Terrain Geology Section, Ontario Geological Survey, Toronto.

INTRODUCTION

The Espanola project area consists of seven townships in the District of Sudbury: Gough, Harrow, May, Salter, Shakespeare, Victoria, and Truman Townships. The first six townships are located west of the Town of Espanola while Truman Township lies to the east.

The purpose of this investigation was to delineate and determine the quality and quantity of aggregate within the area for road-building and general construction uses. This information was required for the evaluation of development potential and land use decisions.

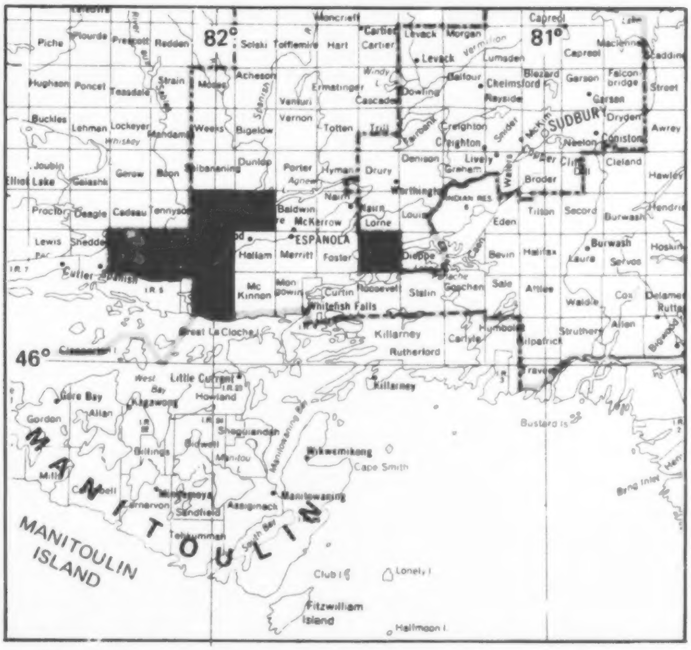
During the field investigation all potential aggregate deposits, and natural and man-made exposures were examined in detail. Observations made at pit sites included the estimation of face height, percentage of gravel and sand, and the amount of objectionable materials present. Soil probing, hand augering, and geophysical techniques were used to assess subsurface materials in areas of limited exposure. A number of test holes were excavated using a backhoe, and aggregate samples were collected for quality testing.

BEDROCK

The bedrock in the project area typically demonstrates a rock knob or rock ridge topography (Gartner 1980; VanDine 1980). A succession of sandstones, siltstones, argillites, greywackes, conglomerates, and carbonate rocks, which make up the Huronian Supergroup, underlie much of the area. In addition, outcrops of granitic rock are common in northern Shakespeare, Gough, May, Salter, and Victoria Townships.

SURFICIAL GEOLOGY AND AGGREGATE POTENTIAL

During the last glacial advance, a veneer of till was deposited on the bedrock in parts of the area (Boissonneau 1968). During the withdrawal of the glacier, ice-contact material was deposited in the form of moraines and esker ridges, and locally, against bedrock knobs. Meltwaters flowing from the receding ice front laid down quantities of outwash material in bedrock valleys. As the ice margin continued to melt back, the area was covered by glacial lakes which occupied the Lake Huron basin. In the waters of these lakes, fine sands, silts, and clays were deposited. These materials generally occupy low-lying areas between bedrock outcrops. In some areas, wave action reworked pre-existing sediments forming glaciolacustrine beaches.



LOCATION MAP

Scale : 1 : 1 548 000
or 1 inch to 25 miles

The most significant aggregate deposits within the report area are outwash features situated along the River aux Saubles, north of Gough Lake and south of Agnew Lake. The material exposed in these deposits predominantly consists of gravelly sand, although pockets and seams of crushable gravel occur locally. Several pits have been developed in these outwash deposits.

Ice-contact features are also common in the area. The sediments exposed in these deposits range from sand to coarse crushable gravel. Many of these deposits flank the southern side of bedrock knobs, and contain only limited resources of aggregate. More extensive deposits of ice-contact material are associated with a moraine ridge which trends east to west across southern Victoria and Salter Townships, and with a north to south trending esker in northern Harrow Township. These deposits have been a traditional source of aggregate in the area.

Large quantities of fine to medium sand of glaciolacustrine origin are available along the Spanish River valley in May, Salter, and Victoria Townships. This material would be suitable for low specification aggregate products such as fill and possibly Granular Base Course 'C'.

With the exception of Truman Township, the townships investigated appear to contain relatively abundant aggregate resources in an area in which aggregate resources are generally considered to be limited (Ontario Geological Survey 1983, in preparation). Pit-run aggregate is likely the most readily produced material from deposits in the area, although reserves of crushable gravel occur locally. The aggregate appears to be hard and durable, and suitable for most road-building and general construction applications.

Aggregate development may be limited by the presence of variable thicknesses of silt and clay which cover several deposits and would require stripping prior to aggregate extraction. In addition, certain deposits in the area contain objectionable quantities of sandstone, argillite, and greywacke clasts which are potentially chemically reactive when used in concrete structures subject to high amounts of moisture/road salts (Rogers 1983).

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34. The Onakawana B Drillhole, District of Cochrane

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INTRODUCTION

Fifty-five years ago, the Ontario Department of Mines conducted a resource evaluation of the Onakawana lignite deposit in the Moose River Basin of northern Ontario. During the program, Ontario Department of Mines drilled one borehole, 'Onakawana A', into the Precambrian basement. This borehole became the standard reference for regional stratigraphy and resource potential of the area.

The original log of Onakawana A (Dyer and Crozier 1933) is now based on an outdated stratigraphic framework. As the core samples no longer exist, relogging of the borehole according to current stratigraphic nomenclature could not be undertaken. To resolve these problems and to obtain additional samples of lignite and potential oil shale, the Ontario Geological Survey drilled Onakawana B (Location Map). This project formed part of the Hydrocarbon Energy Resources Program.

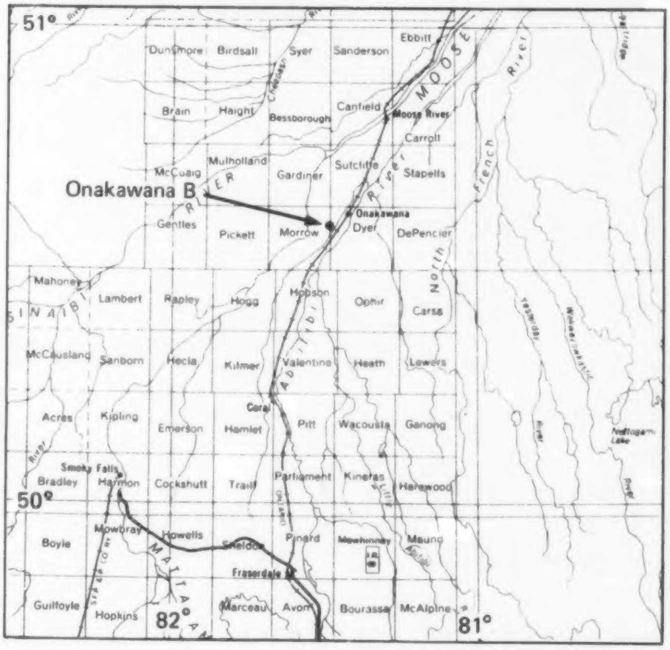
The drilling of Onakawana B (at the same site as Onakawana A) was completed in March 1985, and the borehole was fully cored from surface to the Precambrian basement. The site is approximately 5 km west of the Onakawana railway siding, 118 km north of Cochrane.

The project was managed for the Ontario Geological Survey by Golder Associates who were solely responsible for the non-geological facets of the program. A final report on the logistical and technical aspects of the operation was submitted and will be released in conjunction with the geological logging of Onakawana B in a forthcoming Ontario Geological Survey Open File Report.

GENERAL GEOLOGY

The Moose River Basin contains an approximately 600 m sequence of Paleozoic and Mesozoic strata overlying the Precambrian basement rocks with the unconsolidated Mesozoic sediments up to several hundred metres thick in some areas. The southern boundary of the basin is marked by a prominent east-trending fault-controlled escarpment separating the rugged Precambrian uplands of the south from the flat swampy lowlands of the basin.

In the southeastern part of the basin, in the vicinity of Onakawana, the Paleozoic and Mesozoic strata are approximately 320 m in thickness. In this vicinity, the Paleozoic strata range in age from Middle to Upper Devonian. Potential oil shales are contained in the Long Rapids Formation, the stratigraphic equivalent of the extensive Upper Devonian black shale facies of eastern North America, which is represented in southern Ontario by the Kettle Point Formation (Sanford and Norris 1975). The Mesozoic sediments are of Lower Cretaceous age and consist entirely of the lignite bearing Mattagami Formation (Telford 1982).


51°
Dunsmore
Birdsall
Syer
Sanderson
Ebbitt
MOOSE
River
Brain
Haight
Bessborough
Canfield
Moose River
Carroll
McCuaig
Mulholland
Gardiner
Sutcliffe
Stapells
Onakawana B
RIVER
Onakawana
Gentles
Pickett
Morrow
Dyer
DePencier
North
French
Mahoney
Lambert
Rapley
Hogg
Hopson
Ophir
Carss
ABITIBI
McCausland
Sanborn
Hecla
Kilmer
Valentine
Heath
Lowers
Acres
Kipling
Emerson
Coral
Hamlet
Pitt
Wacousta
Ganong
Smoky Falls
Bradley
Hanlon
Cockshutt
Traill
Parliament
Kineras
Harewood
50°
Boyle
Mowbray
Howells
Sheldon
Pinard
Newkinney
Maund
Fraserdale
MATTAGAMI
Guilfoyle
Hopkins
82°
Marceau
Avon
Bourassa
McAlpine
81°

LOCATION MAP

Scale : 1 : 1 584 000 or
1 inch to 25 miles

The entire region is blanketed by Pleistocene glacial and glaciolacustrine deposits and Recent marine clays up to 200 m in thickness (Skinner 1973). In the Onakawana B area, these surficial deposits are approximately 30 m in thickness.

ONAKAWANA B DRILLING

Drilling of the borehole near Onakawana commenced in mid-February and was completed in late March 1985. It was located at Latitude 50°35′12″N and Longitude 81°29′10″W approximately 5 km west of the Onakawana railway siding and 118 km north of Cochrane along the Ontario Northland Railway (ONR) line to Moosonee. Equipment and personnel were transported via the ONR from Cochrane to Onakawana. Golder Associates, responsible for the management of logistical and drilling operations, rented an ONR rail camp, which was stationed at the Onakawana railway siding, and subcontracted the drilling to Longyear Canada Incorporated of North Bay.

The borehole was continuously cored from surface to the Precambrian with excellent recovery rates. The hole was terminated in weathered Precambrian rock at a depth of 321 m (1053 feet). The generalized stratigraphy of the Onakawana B borehole is as follows:

0-5.5 m (0′-18′): No recovery (probably recent sediments eg. peat)

5.5-21.9 m (18′-72′): Pleistocene tills and lacustrine clays

21.9-76.8 m (72′-252′): Mesozoic; Cretaceous lignite and carbonaceous refractory clay

76.8-156.1 m (252′-512′): Paleozoic; Upper Devonian Long Rapids Formation, brown shale becoming petroliferous with depth, interbedded with green clay/mudstone.

156.1-313.6 m (512′-1029′): Paleozoic; Middle Devonian limestone, collapse breccias, dolomitic limestone, dolostone and mudstone, some gypsum lenses

313.6-320.9 m (1029′-1053′): Precambrian; very weathered granite

DISCUSSION

The original Onakawana A drill log presented certain anomalies and uncertainties which could not be evaluated because of the lack of drill core samples. For example, the reported thickness of clays and shales of the Long Rapids Formation was much greater than other surface and subsurface sections in the area. Difficulty also was encountered in attempting to correlate the various Middle Devonian limestone units described by Dyer and Crozier (1933) with those subsequently defined for the Moose River Basin by Sanford and Norris (1975).

The drilling of Onakawana B confirmed that the Long Rapids Formation is anomalously thick in the Onakawana area. The upper 22 m (72 feet) of the unit actually consist of poorly consolidated green-grey clay and shale. The proportion of black petroliferous shale increases with depth, although greenish clays and concretionary carbonate horizons are common in the lower third of the formation.

The Middle Devonian limestones intersected in Onakawana B could be readily subdivided into the Williams Island, Murray Island, and Moose River Formations as defined by Sanford and Norris (1975). The basal few metres of Paleozoic strata had an unusual lithology of coarse sandstone with scattered gypsum horizons.

A new discovery in Onakawana B was a 1.5 m (5 foot) lignite seam near the base of the Cretaceous Mattagami Formation. This feature had not been reported in Onakawana A and, if it is laterally extensive, it could add significantly to the lignite resources of the Onakawana deposit.

All core from Onakawana B is available for inspection at the Ministry of Northern Affairs and Mines Core Library in Timmins. Additional detailed palynological and sedimentological studies of the drill core are being undertaken by researchers at the University of Toronto and McMaster and Laurentian Universities. An Ontario Geological Survey Open File Report providing full details of the Onakawana B drilling operations and geological results is to be released in the near future.

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GEOPHYSICS/GEOCHEMISTRY PROGRAMS

Summary of Activities 1985, Geophysics/Geochemistry Section

R.B. Barlow

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GEOPHYSICAL PROGRAM

During the 1985 field season, the Night Hawk geophysical test range near Timmins, Ontario was utilized for testing, research and instruction purposes by personnel from industry, university and government. Section staff carried out field work using an ELFAST RTX/HL-30 electromagnetic system based on a standard large loop, fixed- source Turam principle. In addition, coverage was obtained using a recently modified MAXMIN III electromagnetic system. Complete grid coverage over the conductive feature was obtained to permit contouring of assorted parameters (Pitcher, Project 35).

The 1984 drill sites and stratigraphic information resulting from the BRIM overburden drilling program were used to determine the effectiveness of specific airborne and ground electromagnetic methods for identifying areas of deep overburden and for exploring the potential of electromagnetic methods for mapping stratigraphic sections (Pitcher, Project S64). Both airborne and ground electromagnetic techniques have considerable potential for mapping Quaternary deposits over resistive bedrock. Electromagnetic instrumentation is rapidly becoming available so that measurements, with high precision and accuracy, can be made on the spectrum of responses associated with rather complex overburden stratigraphy. An equal requirement exists at present for field studies directed at improving our ability to interpret these complex signatures.

Utilizing the existing Federal-Provincial aeromagnetic information, a project was initiated to attempt to derive basement depths in the Cobalt Embayment area. A range of depths from 900 to 1800 m was found to be in agreement with sparse drilling information in the area (Gupta, Project 36).

GEOCHEMISTRY PROGRAM

The second year of a reconnaissance till sampling project was carried out in cooperation with the Engineering and Terrain Geology Section and formed part of the Black River-Matheson (BRIM) Program. For the second year the project utilized backhoe and sonic drilling techniques to collect till samples for Quaternary and geochemical studies (Baker *et al.* Project S63).

For the second year, work continued on a project which combined remote sensing techniques with multi-parameter lake water/sediment analysis for the purpose of developing a method of identifying lakes affected by acid precipitation in an area north of Sault Ste. Marie, Ontario (Fortescue and Webb, Project 37).

A regional multi-element lake sediment geochemical study of Michipicoten Island was undertaken in August of this year. Measurements of pH, conductivity, temperature, dissolved oxygen and Secchi depth were recorded, and sediment cores were collected for analysis at 94 sites. The resulting information will be of value in determining any mineral potential that may exist on the island. In addition, the data may reflect interesting environmental patterns with respect to existing data collected previously in the northern shore area of Lake Superior (Fortescue and Webb, Project 38).

GEOCHRONOLOGY PROGRAM

An extensive geochronological project has been completed in 1985 in the Batchawana area. The data indicate that volcanism and early plutonism occurred mainly between 2730 and 2700 Ma ago. This was followed by subsidence and sedimentation and concluded by folding, metamorphism and syn- to late-tectonic plutonism at 2677 Ma ago. Post-tectonic plutons were emplaced at 2673 and 2668 Ma ago.

Plutonic and metamorphic activity lasted much longer at deeper crustal levels of the same belt. This is documented by zircon ages of 2670 to 2660 Ma and monazite and titanite ages of 2654 to 2637 Ma ago in the Agawa area which represents the southwestern extension of the Kapuskasing Zone.

An areal distinction in the time of major metamorphism is revealed by U-Pb data in the English River Subprovince. The main metamorphism in the Kenora area occurred at about 2710 Ma ago and was essentially terminated by 2690 Ma ago whereas high-grade metamorphism in the Cedar Lake area occurred later at about 2680 Ma ago. Titanite and apatite data in this area record a protracted period of subsequent lower-grade activity. New data also show that tonalites were formed during at least five distinct periods in the English River Subprovince, commencing at least 3180 Ma ago and lasting until 2710 Ma ago.

Another project was concluded in the Shebandowan belt. The data obtained span the period between 2730 and 2680 Ma and put constraints on the age of Timiskaming-type sedimentation and volcanism and on two major episodes of deformation, the second one of critical importance for the localization of gold deposits in the region.

Dating in progress in the Red Lake belt provides further ages contributing to an enhanced understanding of the chronostratigraphic evolution of the belt and resolving the time of the structural, metamorphic and plutonic events related to the formation of the area's major gold mineralizations.

Other projects in progress in northwestern Ontario include dating of supracrustal sequences in the Favourable Lake area and in the eastern Uchi Subprovince. Preliminary data have also been obtained in the Geraldton and in the Hemlo gold camps.

Geochronology on an altered and mineralized Nipissing diabase at Gowganda yield a baddeleyite and rutile age of 2219 Ma which dates emplacement of the dike and perhaps also the silver-mineralizing event.

35. Night Hawk Geophysical Test Range Results, District of Cochrane

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INTRODUCTION

Staff of the Geophysics/Geochemistry Section continued studies during the 1985 summer field season on the Night Hawk Geophysical Test Range (Barlow 1981; Barlow *et al.* 1982; Pitcher *et al.* 1983; Barlow 1984). These studies included surveys employing the ELFAST RTX/HL-30 and the recently upgraded MAX-MIN III+ frequency domain electromagnetic systems.

The test range program was initiated with the objective of developing certain areas, which are representative of exploration targets in Ontario, into sites for testing newly developed exploration technology. Sites that are selected for this purpose will be subject to ongoing tests using new geophysical equipment by Section staff and/or research scientists from university departments, industrial research and development groups, and staff scientists from the Geological Survey of Canada. The test ranges will, therefore, serve as field laboratories for geophysical research groups, thus aiding an important phase of exploration technology development. In addition, the sites will provide areas for instruction of field techniques in exploration geophysics.

In addition to the work carried out by the Ontario Geological Survey, geophysical instrument manufacturers and airborne geophysical survey contractors continued to carry out field tests throughout 1985. As well, the Geophysics Department of the University of Toronto used the site for their annual field school in September.

LOCATION AND ACCESS

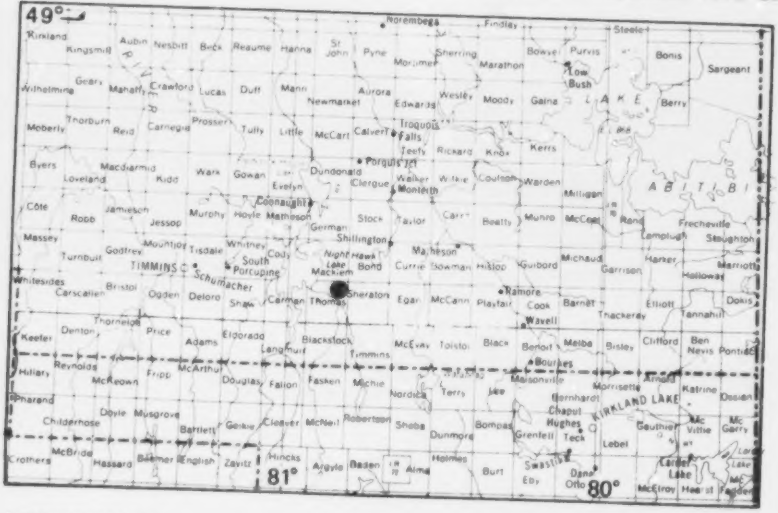
The Night Hawk test range is located in the northeastern quadrant of Thomas Township, approximately 12 km south of Highway 101, on the Gibson Lake Road. The Gibson Lake turnoff is approximately 40 km east on Highway 101 from Timmins, Ontario.

Figure 1 illustrates the grid, the 1985 ELFAST transmitter loop positions, previous drillholes, the navigation control line, and a number of access roads throughout the grid system.

ELFAST DATA

The ELFAST RTX/HL-30 (Extra Low Frequency Automatic Scanning Turam) system is a fixed source electromagnetic system based on the standard fixed-source Turam principle. The conventional procedure is to lay out a rectangular transmitter loop, through which an alternating current flows, and to survey a number of lines that are, firstly perpendicular to the long side of the loop and, secondly, perpendicular to the probable conductor trend using two receiver coils, in this case, separated by 50 m. Recently, Duckworth and Bays (1984) described a modified mode of operation for the Turam method which employs rectangular transmitter loops whose long side is perpendicular to the probable conductor trend and the survey lines are parallel to the long side of the loop. The principle advantages of the modified method are the provision of unlimited traverse extent by simply increasing the size of the loop and the freedom to use larger coil spacings for greater depth of investigation. The modified mode, however, offers the inherent disadvantage of poorer coupling between the transmitter loop and thin steeply dipping conductors at right angles to the long side of the loop. This limitation does not appear to exist in the Night Hawk results.

The ELFAST version of the Turam method allows the measurement at 5 frequencies, 25, 75, 225, 675, and 2025 Hz, of absolute field strength at each re-


49°
Kirkland
Kingsmill
Aubin
Nesbitt
Beck
Reaume
Hanna
St John
Pyne
Mortimer
Norembega
Sherring
Findlay
Marathon
Bowyer
Purvis
Low Bush
Steele
Bonis
Sargeant
Wilhelmina
Geary
Mahaffy
Crawford
Lucas
Duff
Mann
Newmarket
Aurora
Edwards
Wesley
Moody
Gaina
LAKE
Berry
Moberly
Thorburn
Reid
Carnegie
Prosser
Tully
Little
McCart
Calvert
Iroquois Falls
Teefy
Rickard
Knox
Kerrs
Porquis Jct
Byers
Macdiarmid
Loveland
Kidd
Wark
Gowan
Evelyn
Dundonald
Clergue
Walker
Wilkie
Monteith
Coulson
Warden
Milligan
ABITIBI
Côte
Robb
Jamieson
Jessop
Murphy
Hoyle
Connaught
Matheson
German
Stock
Taylor
Carr
Beatty
Munro
McCool
Rand
Frecheville
Lamplugh
Staughton
Massey
Turnbull
Godfrey
Mountjoy
Tisdale
Whitney
Cody
Shillington
Night Hawk Lake
Matheson
TIMMINS
South Porcupine
Schumacher
Mackiem
Bond
Currie
Bowman
Hislop
Guibord
Michaud
Garrison
Harker
Holloway
Marriott
Whitesides
Carscallen
Bristol
Ogden
Deloro
Shaw
Carman
Thomas
Sheraton
Egar
McCann
Playfair
Ramore
Cook
Barnet
Thackeray
Elliott
Tannahill
Dokis
Wavell
Keefer
Denton
Thorneloe
Price
Adams
Eldorado
Langmuir
Blackstock
Timmins
McEvay
Tolstoi
Black
Benoit
Melba
Bisley
Clifford
Ben Nevis
Pontiac
Bourkes
Hillary
Reynolds
McKeown
Fripp
McArthur
Douglas
Fallon
Fasken
Michie
Nordica
Terry
Maisonville
Morrisette
Arnold
Katrine
Ossian
Pharand
Childerhose
Doyle
Musgrove
Bartlett
Geikie
Cleaver
McNeil
Robertson
Sheba
Dunmore
Bompas
Bernhardt
Chaput Hughes
KIRKLAND LAKE
Grenfell
Teck
Lebel
Gauthier
Mc Vittie
Mc Garry
Crothers
McBride
Hassard
Beemer
English
Zavitz
Hincks
81°
Argyle
Baden
Alma
Holmes
Burt
Swastika
Eby
Dane
Otto
80°
Larder Lake
McElroy
Hearst
McFadden

LOCATION MAP

Scale : 1 : 1 548 000 or 1 inch to 25 miles

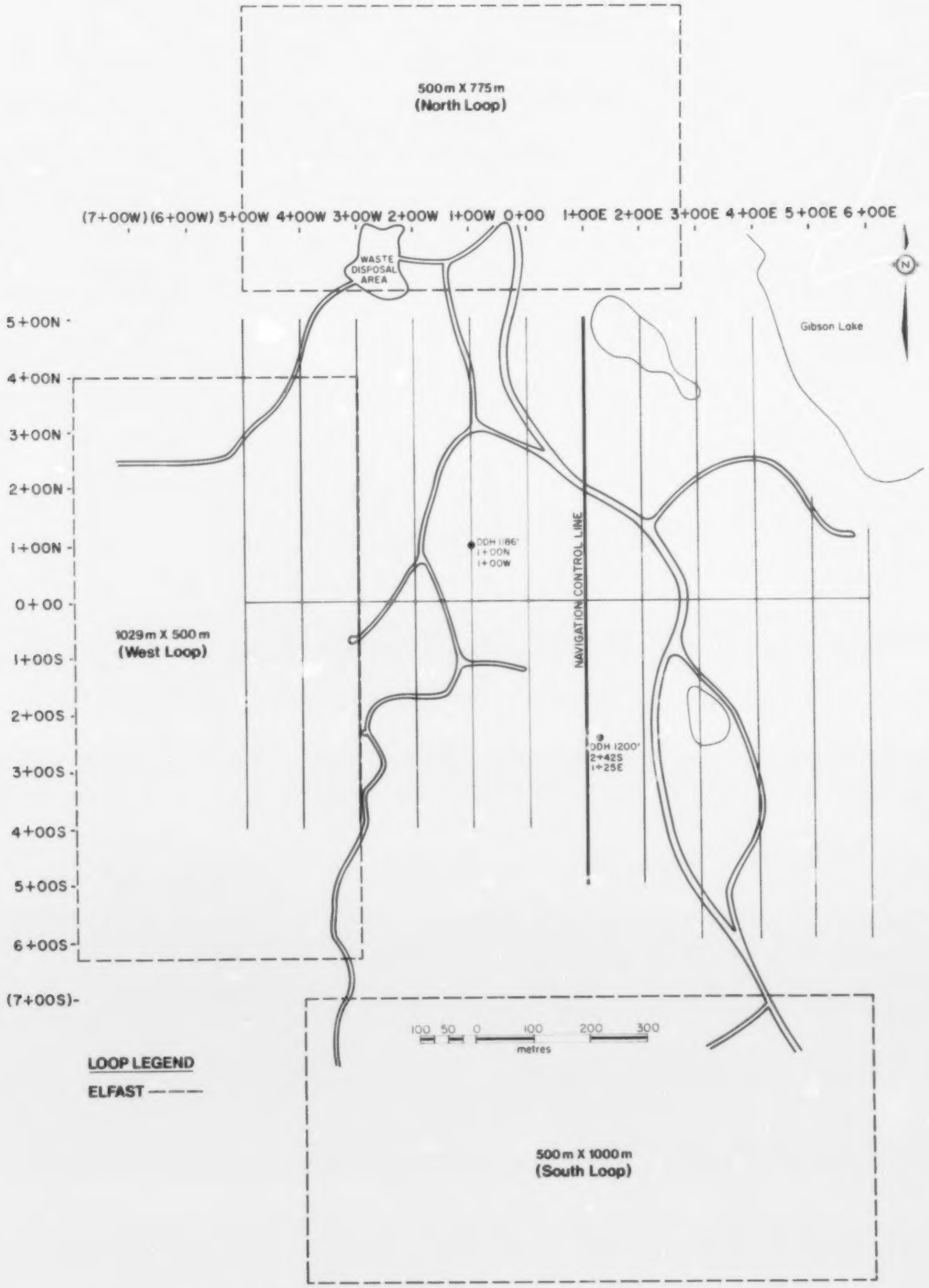

500 m X 775 m
(North Loop)
(7+00W)
(6+00W)
5+00W
4+00W
3+00W
2+00W
1+00W
0+00
1+00E
2+00E
3+00E
4+00E
5+00E
6+00E
N
WASTE DISPOSAL AREA
Gibson Lake
5+00N
4+00N
3+00N
2+00N
1+00N
0+00
1+00S
2+00S
3+00S
4+00S
5+00S
6+00S
(7+00S)
ODH 1186'
1+00N
1+00W
NAVIGATION CONTROL LINE
ODH 1200'
2+42S
1+25E
1029 m X 500 m
(West Loop)
100
50
0
100
200
300
metres
LOOP LEGEND
ELFAST ----
500 m X 1000 m
(South Loop)

Figure 1. Grid location map for the Night Hawk Geophysical Test Range. (Project 35.)

ceiver coil and the phase difference between the received field at each coil. Normally, two parameters are presented in profile form:

1. Reduced Field Strength Ratio - observed field strength ratio V_1/V_2 normalized by the calculated primary field strength ratio.
2. Phase difference - measured phase gradient between the received fields at coil 1 and coil 2.

Other parameters that are presented employing the Turam method are used to further remove the effect of loop position on target response and to separate in-phase and quadrature fields from the measured data. Three such parameters are:

1. Reduced Secondary Field Difference-smoothed horizontal derivative of the secondary field normalized to the local primary field in percent.
2. Reduced In-phase Field-smoothed horizontal derivative of the in-phase component of the secondary field normalized to the local primary field in percent using the accumulated phase.
3. Reduced Quadrature Field-smoothed horizontal derivative of the quadrature component of the secondary field normalized to the local primary field in percent using the accumulated phase.

Complete coverage over the most conductive trends was attained by surveying the seven lines from 2+00 West to 4+00 East at 25 m station separations from 4+00 South to 2+25 North. Both conventional Turam employing North and South Loops and the modified Turam technique employing a West Loop were used in the field tests (Figure 1). Profiles of the type presented in Figure 2 were generated by computer plotter of the survey data. Contour maps of the reduced field strength ratio and the phase difference at the five different frequencies of the type presented in Figure 3 were computer plotter generated for the complete set of survey date.

The following observations are made from the plotted results:

CONVENTIONAL TURAM

1. At low frequency, two different trends are defined depending upon which loop is employed. Moreover, the trend closer to the loop is always the one that is delineated.
2. At high frequency employing the North Loop, the reduced field strength ratio defines two conductor trends.
3. At high frequency, the phase difference peaks over the trend that is farther from the loop.

MODIFIED TURAM

1. Both the reduced field strength and the phase difference define two distinct current flows of opposite polarity.

MAXMIN DATA

The MAXMIN data collected during the 1985 summer field program and presented herein was obtained using the MAXMIN III+ which is an upgraded MAXMIN III unit. The major upgrades of the unit included:

1. Replacement of the ferrite antenna and retuning the associated circuitry.
2. Modification of the digital and DC low-pass noise filtering circuitry.
3. Expansion of the maximum coil separation capability from 300 m to 400 m.

The aim of these modifications is to improve the signal to noise ratio of the system to allow rapid measurements at large coil separations, even under noisy conditions.

Complete coverage of the major conductive zones over the grid system was achieved by carrying out 100, 150, 200 and 300 m coil separation traverses on lines 2+00 West to 4+00 East. The station spacing was 25 m and measurements of the in-phase and quadrature components were taken at the 5 MAXMIN frequencies, 111, 222, 444, 888, and 1777 Hz.

These results were computer plotted in both profile (Figure 4) and contour (Figures 5 and 6) form. The anomaly pattern develops from (1) a reverse sign (positive anomaly) on the 100 m data to, (2) two distinct standard negative "horizontal loop" type anomalies on the 200 m data to, (3) a single broad anomaly on the 300 m data. It should be noted that the contour closures near the lake on line 3+00 East, particularly on the shortest coil spacing in-phase data is due to the traverse around the lake and the subsequent coil separation errors.

FUTURE ACTIVITIES

Upon completion of this year's field work on the Test Range, a comprehensive database now exists for a variety of geophysical methods, including both time and frequency domain electromagnetics (fixed and moving source), potential field data (gravity and magnetics) and seismic. Hence, work will be underway in 1986 to produce an atlas of these results for eventual open file release.

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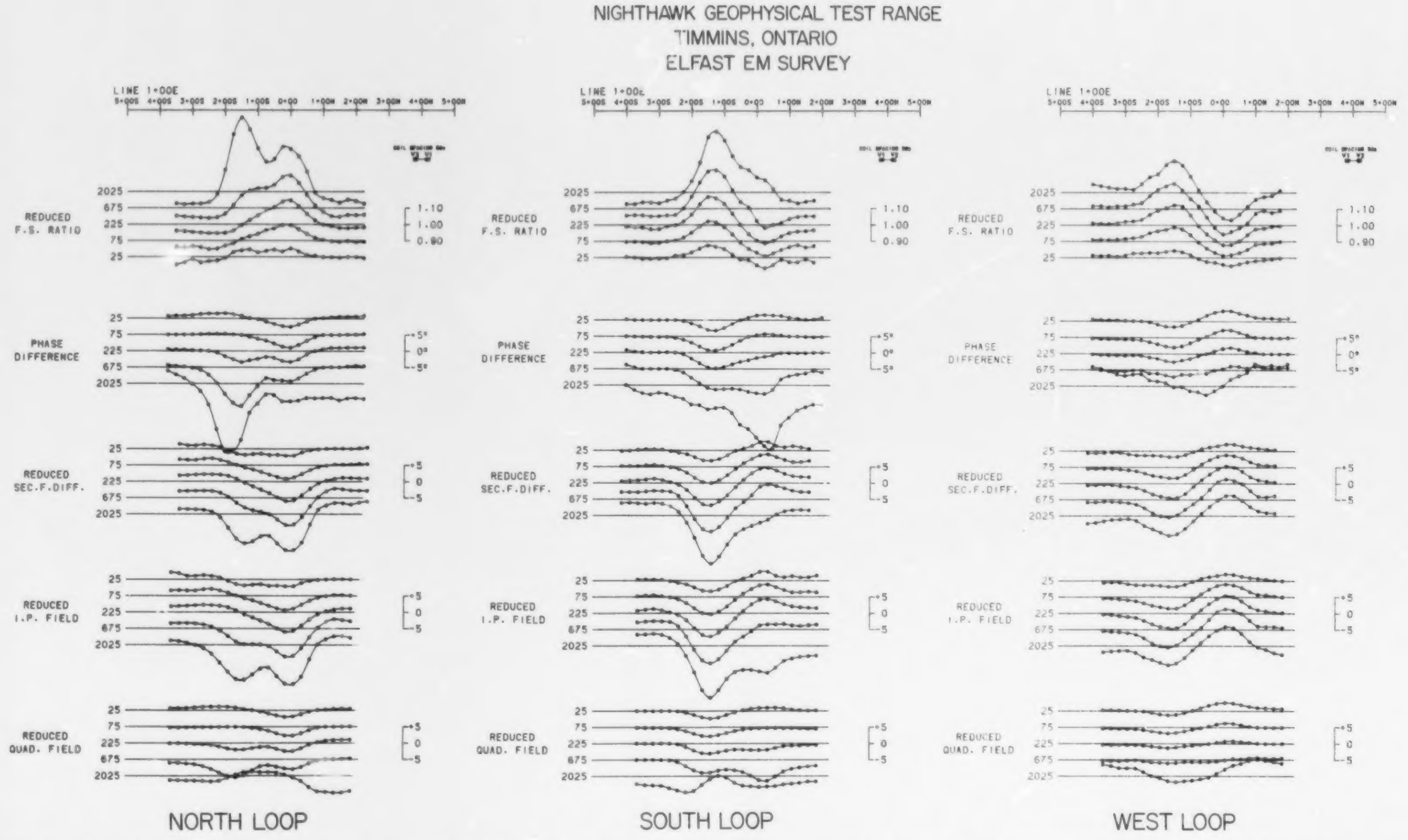

Figure 2. ELFAST profiles using 3 different transmitter loops (North, South, and West Loops) and a receiver coil separation of 50 m over Line 1+00 East. (Project 35.)

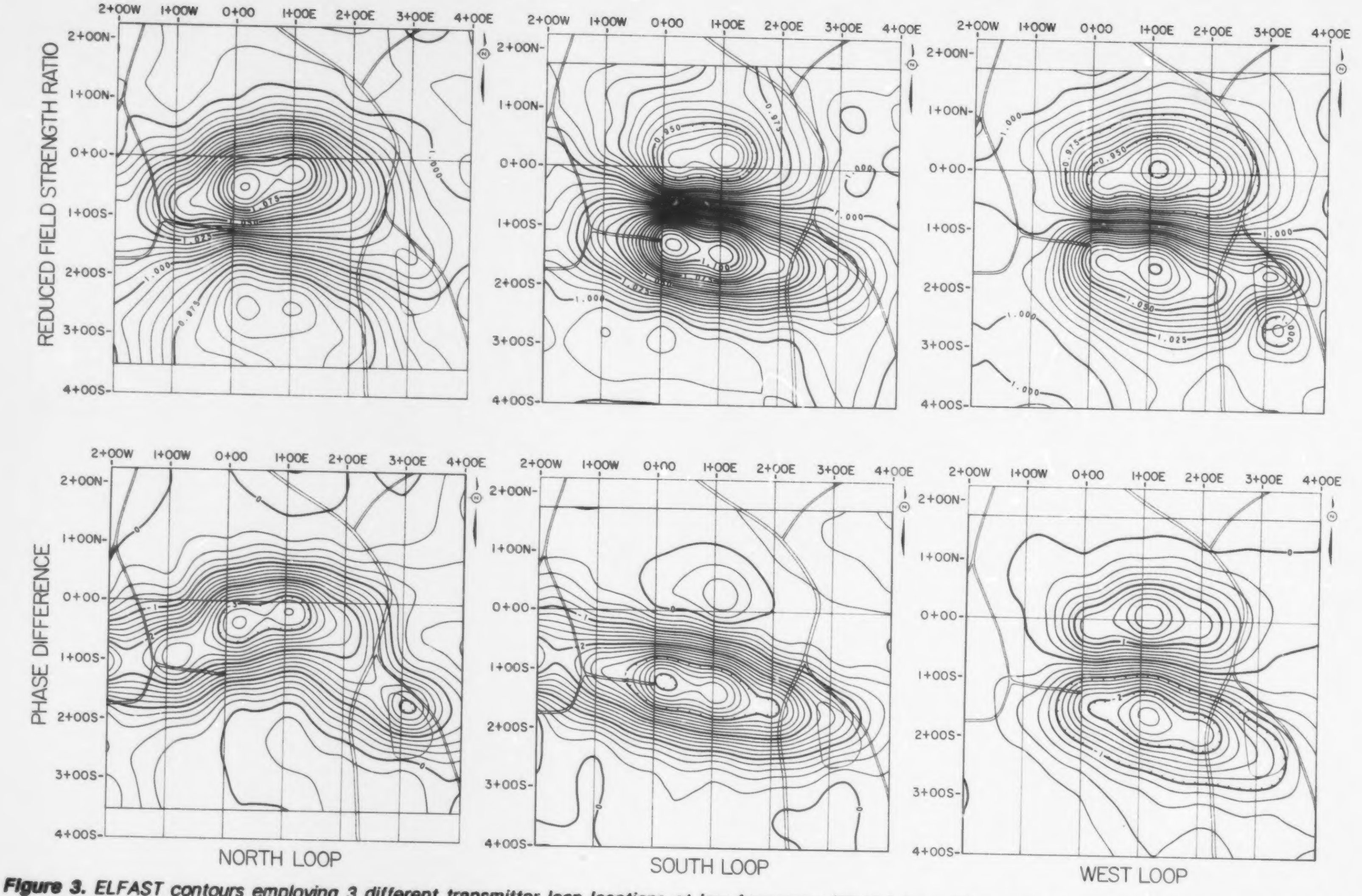
REDUCED FIELD STRENGTH RATIO
PHASE DIFFERENCE
NORTH LOOP
SOUTH LOOP
WEST LOOP
2+00W
1+00W
0+00
1+00E
2+00E
3+00E
4+00E
2+00N
1+00N
0+00
1+00S
2+00S
3+00S
4+00S
N
0.975
0.950
1.000
1.025
1.050
1.100
0
1
2

Figure 3. ELFAST contours employing 3 different transmitter loop locations at low frequency (75 Hz) for a 50 m coil separation. The contour interval of the reduced field strength ratio is 0.005 and the contour interval of the phase difference is 0.2 degrees. (Project 35.)

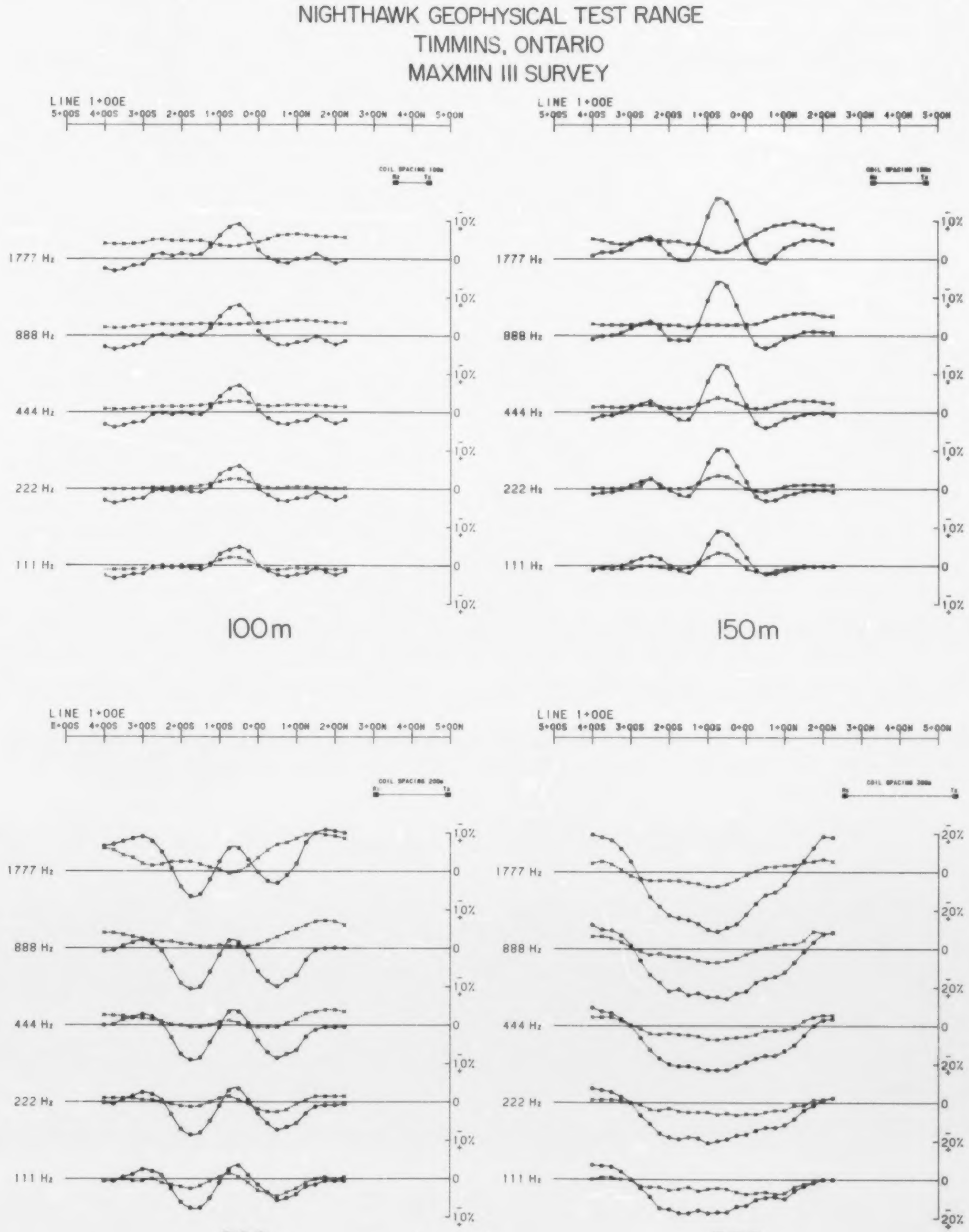

Figure 4. *MAXMIN III+ profiles using a 100 m, 150 m, 200 m and 300 m coil separation over line 1+00 East. (Project 35.)*

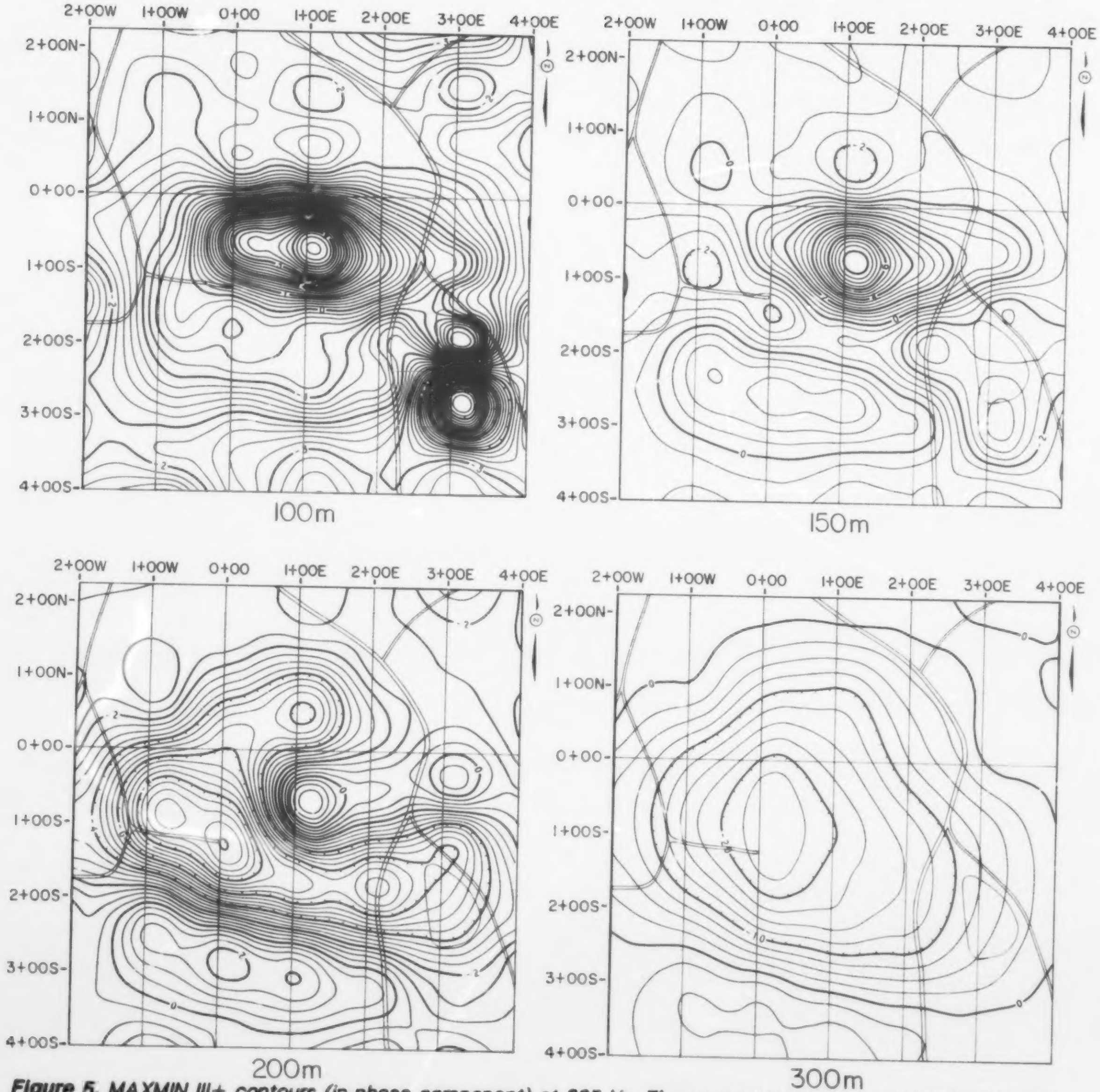
2+00W
1+00W
0+00
1+00E
2+00E
3+00E
4+00E
2+00N
1+00N
0+00
1+00S
2+00S
3+00S
4+00S
100m
150m
200m
300m

Figure 5. *MAXMIN III+ contours (in-phase component) at 225 Hz. The contour intervals are 0.2% for the 100 m data, 0.5% for the 150 and 200 m data, and 2.5% for the 300 m data. (Project 35.)*

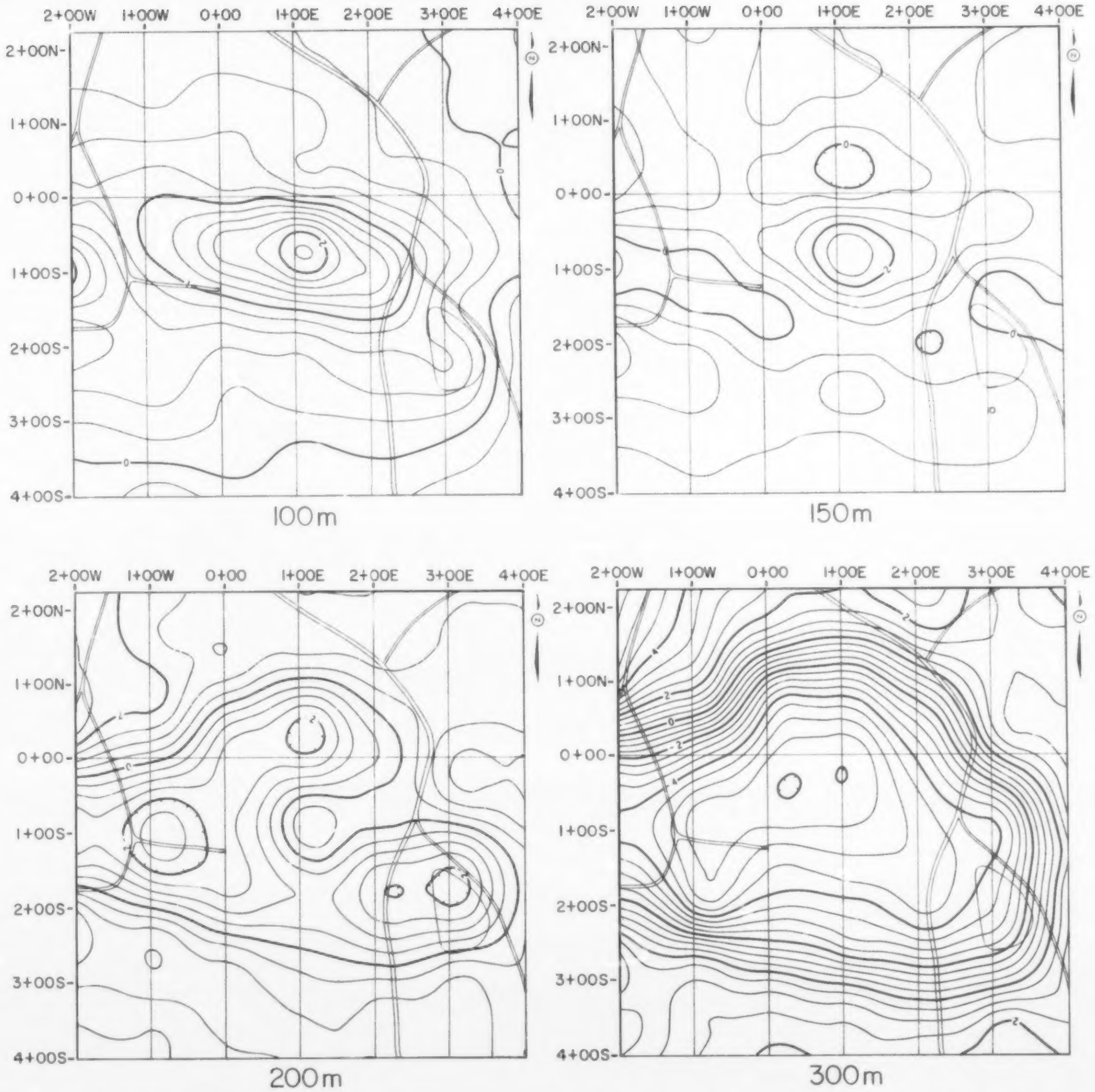

Figure 6. MAXMIN III+ contours (quadrature component) at 225 Hz. The contour intervals are 0.2% for the 100 m data, and 0.5% for the 150, 200 and 300 m data. (Project 35.)

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36. Cobalt Embayment Interpretation: Depth to Basement and Distribution of Nipissing Diabase from Aeromagnetics

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INTRODUCTION

The Cobalt Embayment, due to its sedimentary cover, is looked upon as an impediment to the search for Early Precambrian mineralization but is also regarded as a potential depository for gold mineralization. It is thought to have some potential for Witwatersrand reef-type gold deposits, which in the Witwatersrand itself are known to be controlled by paleogeomorphology (Pretorius 1981). It is, therefore, desirable to know the form and relief of the Archean surface beneath the Huronian Supergroup sedimentary rocks of the Cobalt Embayment.

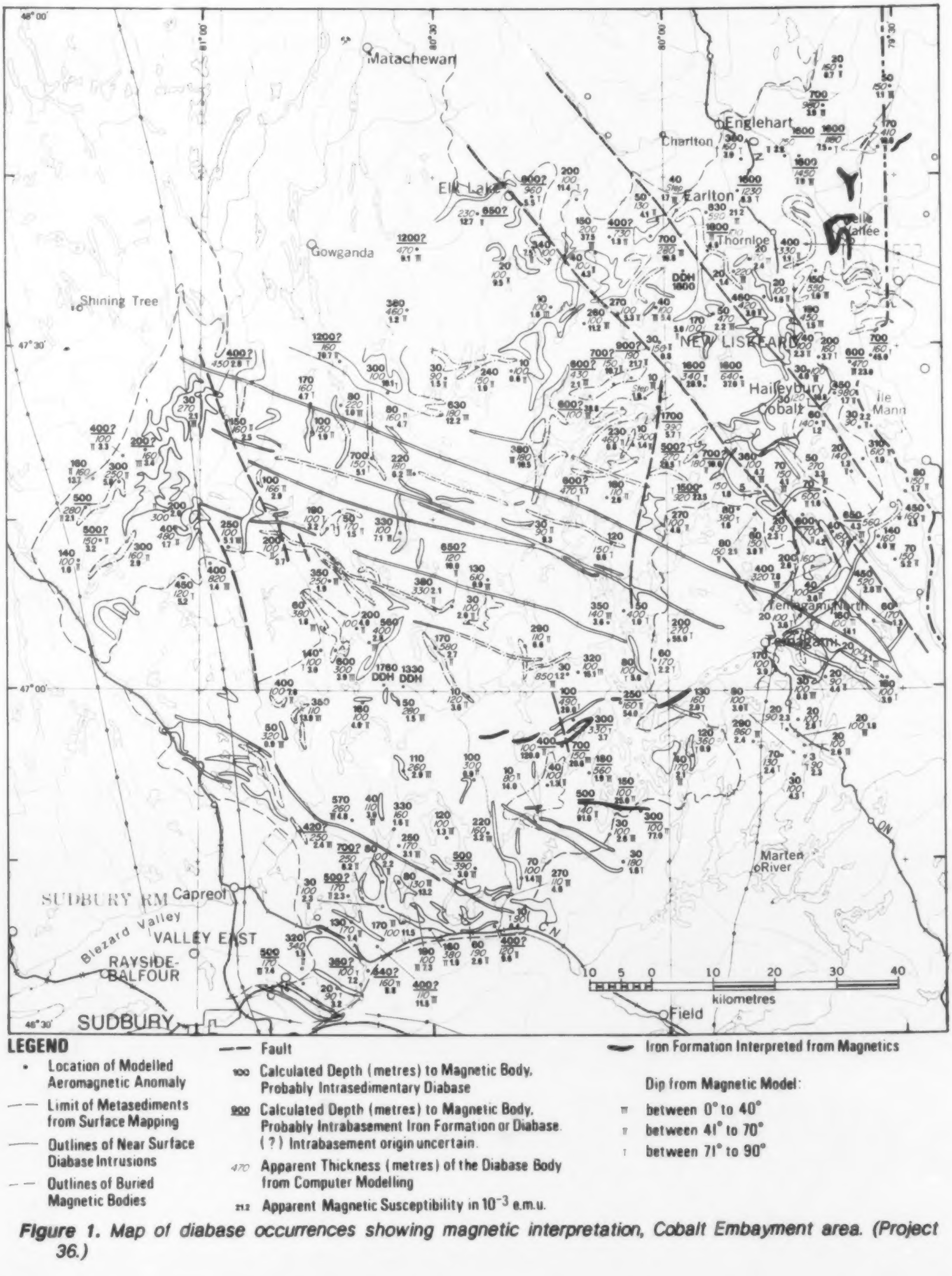
A systematic semidetailed gravity survey and interpretation of the Cobalt Embayment area was recently undertaken (Gupta and Grant, in press; Gupta 1981a, 1981b; Gupta and Wadge 1980a, 1980b). A mantle of Early Proterozoic sedimentary rocks covers much of the region, effectively masking the Archean rocks that may contain Archean mineral deposits. The sedimentary rocks consist mainly of wackes, siltstones, arkoses, quartzites, and pebble conglomerates. Their thickness has been tested by diamond drilling at only two locations (Thomson 1968), but surface mapping indicates a maximum potential thickness in excess of 6 km. One of the objectives of the gravity survey was to analyze the gravity anomalies in order to compute the thickening or thinning of the sedimentary rocks of the Huronian Supergroup. From these thickness calculations, one can construct a generalized map of the underlying basement topography. Unfortunately, the gravity method is unable to give any direct information about the thickness of the sedimentary rocks of the Huronian Supergroup in the Cobalt Embayment, because their average density (2.74 g/cm^3) is virtually the same as that of the surrounding and underlying gneissic and migmatitic rocks (2.73 g/cm^3), resulting in a lack of density contrast (i.e. no gravity effect) from the interface. An attempt was therefore made to interpret the existing aeromagnetic maps to determine the depth to the top of the Archean basement and to determine the distribution of the Nipissing diabase. A total field aeromagnetic survey was flown over this region in 1959 and 1960 by the then Ontario Department of Mines and the Geological Survey of Canada, using a fluxgate magnetometer. The mean flight line spacing was 0.5 mile and the mean terrain clearance was 1000 feet. From an examination of the aeromagnetic contour maps, it is quite evident that many of the aeromagnetic anomalies originate from intrusions of diabase-gabbro into the Huronian Supergroup sedimentary rocks. Generally, it is difficult to perceive any magnetic characteristics of diabase anomalies that would distinguish them from magnetic anomalies which have their origin in the basement rocks. Since little factual information is known about the extent and depth of burial of the Nipissing diabase, the decision was taken to computer model as many magnetic anomalies as possible, in order to separate the suprabasement features from the intrabasement bodies according to the calculated values of their depths, dips, and magnetic strength. Although it is quite impossible to determine whether the diabases are intrabasement or suprabasement from their external magnetic fields, Archean iron formations, although few in number, definitely belong to the basement complex, and are easy to recognize due to the large amplitudes of their magnetic effects.

DEPTH CALCULATIONS FROM TOTAL FIELD MAPS

Within the Cobalt Embayment region, 222 aeromagnetic anomalies were analyzed by computer using two-dimensional model fitting methods, assuming induced magnetization. Of these, 195 anomalies proved to be due to bodies at depths of 0 to 600 m, many of which appeared to be gently dipping with apparent magnetic susceptibilities in the range 1-4 x 10^{-3} e.m.u., or 1-5 x 10^{-2} S.I. units. These are assumed to be diabase intrusions. Only about 20 aeromagnetic anomalies could positively be identified with basement rocks believed to be caused by iron formations (*see* Figure 1). Since all of the known iron formations in the project area are Archean in age, they are thought to provide local estimates of depth to basement which are fairly reliable. In making anomaly calculations, the remanent magnetization has been ignored. However, Symons *et al.* (1980) have shown that, for example, in the Moose Mountain area, located in a window of Archean rocks surrounded by unconformably overlying Proterozoic rocks of the Cobalt Embayment, the natural remanent magnetization of the iron formation augments the induced magnetization by +24%. The number of reliable basement depth estimates obtainable from the aeromagnetic anomalies is too small and therefore a generalized sediment thickness contour map cannot be prepared from these results. Most of the calculations of basement depth in the Cobalt Embayment (Figure 1) fall into the range 900 to 1800 m, which is consistent with the very meagre amount of available drilling information (*see* Thomson 1968).

DISTRIBUTION OF NIPISSING DIABASE

One of the controversial questions relating to the genesis of polymetallic ores in the Cobalt Embayment concerns the role that may have been played by igneous intrusions, and specifically by intrusions of Nipissing diabase, in providing sources of heat for concentrating the ores in veins and stockworks (Patterson 1979; Innes and Colvine 1979). If this hypothesis is valid, it is clearly desirable to map the distribution of diabase intrusions within the Cobalt Embayment.


48°00'
81°00'
80°30'
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79°30'
47°30'
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Matachewan
Englehart
Charlton
Elk Lake
Earlton
Thornloe
Gowganda
Shining Tree
NEW LISKEARD
Haileybury
Cobalt
Ile Mann
Temagami North
Temagami
Marten River
SUDBURY RM
Capreol
Blezard Valley
VALLEY EAST
RAYSIDE-BALFOUR
SUDBURY
Field
CN
ON
DDH
10 5 0 10 20 30 40
kilometres
LEGEND
Location of Modelled Aeromagnetic Anomaly
Limit of Metasediments from Surface Mapping
Outlines of Near Surface Diabase Intrusions
Outlines of Buried Magnetic Bodies
Fault
100 Calculated Depth (metres) to Magnetic Body. Probably Intrasedimentary Diabase
900 Calculated Depth (metres) to Magnetic Body. Probably Intrabasement Iron Formation or Diabase. (?) Intrabasement origin uncertain.
470 Apparent Thickness (metres) of the Diabase Body from Computer Modelling
212 Apparent Magnetic Susceptibility in 10-3 e.m.u.
Iron Formation Interpreted from Magnetics
Dip from Magnetic Model:
between 0° to 40°
between 41° to 70°
between 71° to 90°

Figure 1. Map of diabase occurrences showing magnetic interpretation, Cobalt Embayment area. (Project 36.)

The intrusions are generally too thin and too small in area to produce gravity disturbances that are discernible in the residual gravity map. Their effects have been removed along with other geological noise during the smoothing that preceded the contouring of the Bouguer gravity data. Many of them, however, contain enough magnetite to cause magnetic anomalies that can be perceived in the aeromagnetic survey. These magnetic anomalies have a distinctly different character than those which are produced by iron formations and by other large magnetic bodies within the basement complex, being generally narrower, of shorter strike length, and smaller in amplitude. Except for dikes, this makes the diabases difficult to recognize and even more difficult to pinpoint in the total field magnetic contours, since they frequently manifest themselves only as minor rough spots in the magnetic field gradients or as noisy wiggles in the contours. To make these small anomalies more visible, they must be magnified and separated from the rest of the geomagnetic field. An appropriate tool for performing this task is the vertical gradient map, since the vertical gradient operator is especially sensitive to magnetic disturbances due to bodies that are shallow, and it discriminates against bodies that are deep. Accordingly, the vertical gradient of the geomagnetic field over the Cobalt Embayment was calculated from the total field data. From an interpretation of the vertical gradient map we have outlined the magnetite-bearing diabase intrusions, which are shown in Figure 1.

The vertical magnetic gradient map does not show all of the diabases within the Cobalt Embayment, since there are probably some that are nonmagnetic. However, it does give a general picture of their horizontal distribution of the 195 magnetic anomalies that were analyzed by two-dimensional computer modelling and which were subsequently attributed to intrusive bodies of Nipissing diabase give a fairly detailed representation of the distribution with depth and of the magnetic properties of these bodies. The results of these analyses are also shown in Figure 1. Most of the intrusions appear to be relatively thin (relative, that is, to their distance below the aircraft), and their estimated magnetic susceptibilities indicate that they contain, on the average, between 1% and 2% by volume of magnetite. According to the calculations, they lie at depths ranging from surface to 500 m. Dips appear to vary from gentle (30°) to steep (90°) if the magnetizations are assumed to be normal, that is, in the direction of the present geomagnetic field. Paleomagnetic studies on Nipissing diabase have been reported by Symons (1967), Symons and Londry (1975), and Patel and Palmer (1974). It has been suggested by Symons and Londry (1975) that the Earth's magnetic field was dominantly reversed during emplacement and cooling of the Nipissing Sills with minor periods of normal polarity. Diabase sills retain a primary remanence that has been verified on samples collected from the Silverfield Mine near the Town of Cobalt (Symons 1967). In spite of the fact that some of these bodies are remanently magnetized, the depth estimates will still be reliable but the dip estimates will have little meaning.

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37. The Relationship Between Geochemical and Remote Sensing Data Obtained in the Vicinity of Barbara Lake and Cowie Lake, District of Algoma

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[1]Geochemist, Geophysics/Geochemistry Section, Ontario Geological Survey.

[2]Geological Assistant, Geophysics/Geochemistry Section, Geological Survey.

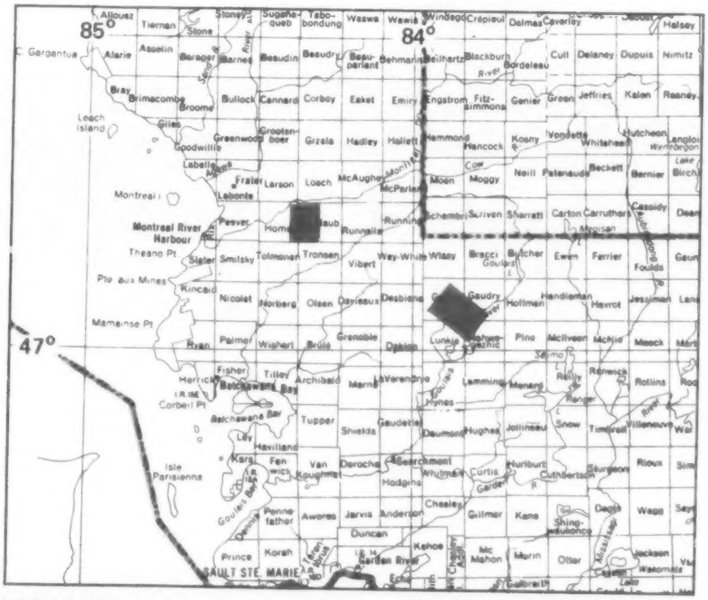
INTRODUCTION

Regional geochemical surveying techniques based on stream or lake sediments have been the subject of experimentation by the Ontario Geological Survey for several years (e.g. stream sediments, Fortescue 1983, 1984a; lake sediments, Fortescue 1985, Fortescue and Webb, this volume; diatom-inferred pH, Fortescue *et al.* 1981, 1984; remote sensing and acid lakes, Fortescue and Diamond 1984, Fortescue *et al.* 1985).

This study is part of an environmental geochemical program which has two goals: (1) to provide a technique for describing the pH history of lakes during the past 100 year period; and (2) to provide a technique for using remote sensing to delineate areas where lakes are likely to be affected by the effects of acid rain. By early in 1984 we were satisfied that the first goal could be reached using properly calibrated diatom-inferred pH measurements on lake sediment cores (Dickman *et al.* 1984, 1985). Independent confirmation of the validity of this approach has been obtained recently in a review by Battarbee and Charles (1985) who state: "Diatom analysis of lake sediments is the most reliable method of reconstructing changes in lake acidity". The Ontario Geological Survey's progress in diatom-inferred pH research was summarized by Fortescue (1984b).

The research leading to the development of the diatom-inferred pH method also indicated that acid lakes in the Canadian Shield tend to occur in clusters associated with local variations in the geological substrate of the catchment areas. For example, where rocks are granitic and calcareous overburden is absent lakes tend to be acid, but where rocks are granitic and the overburden is calcareous the lakes are usually normal. Consequently, acid and normal lakes may occur side by side in the same area although experience has shown that acid lakes tend to occur in clusters. Clearly, if such clusters of acid lakes could be identified ahead of planning future regional geochemical surveys then special attention could be given to the study of acid lakes during the field survey with the minimum of disturbance to the geochemical survey program as a whole.

Other research associated with the diatom-inferred pH studies (Fortescue 1984b) demonstrated that acid lakes with a pH of less than 5.6 are of two general types: (1) humic lakes, which are naturally acid; and (2) clear lakes which are also acid. The clear lakes are of particular interest in relation to the acid rain problem. Consequently, the goal of our acid rain research during 1984/5 and 1985/6 has been directed to the recognition of clusters of clear, acid, lakes in the Canadian Shield. Remote sensing has been used extensively in the attempt to find a reliable solution to this difficult problem.


85°
84°
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Allouez
Tiernan
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Sugana-queb
Tabo-bondung
Waswa
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Dalmas
Caverley
Halsey
C. Gargantua
Alarie
Asselin
Barager
Barnes
Beaudin
Beaudry
Beau-parlant
Behmann
Beilhartz
Blackburn
River
Bordeleau
Cull
Delaney
Dupuis
Nimitz
Bray
Brimacombe
Broome
Bullock
Cannard
Corboy
Eaket
Emiry
Engstrom
Fitz-simmons
Genier
Green
Jeffries
Kalen
Reaney
Leach Island
Giles
Goodwillie
Greenwood
Grooten-boer
Grzela
Hadley
Hallett
Hammond
Hancock
Kosny
Vondette
Whitehead
Hutcheon
Langlois
Wenebegon
Labelle
Fraler
Larson
Loach
McAughey
Montreal
McParland
Moen
Cow
Moggy
Neill
Patenaude
Beckett
Bernier
Lake
Birch
Montreal I.
Labonte
Montreal River Harbour
Peever
Home
Raub
Runnalls
Running
Schembri
Scriven
Sherratt
Carton
Carruthers
Megisan
Cassidy
Dean
Theano Pt.
Slater
Smilsky
Tolmonen
Tronsen
Vibert
Way-White
Wlasy
Bracci
Butcher
Goulais
Ewen
Ferrier
Foulds
Gaudette
Pte aux Mines
Kincaid
Nicolet
Norberg
Olsen
Dayieaux
Desbiens
Gaudry
Hoffman
Handleman
Havrot
Jessiman
Mamainse Pt
Ryan
Palmer
Wishart
Brule
Grenoble
Dablon
Lunkie
Pine
McIlveen
McNie
Meech
Herrick
Fisher
Tilley
Archibald
Marne
LaVerendrye
Lamming
Menard
Reilly
Rollins
Corbeil Pt
Batchawana Bay
Hynes
Ranger
Tupper
Shields
Gaudette
Daumont
Hughes
Jollineau
Snow
Timmerell
Villeneuve
Havilland
Isle Parisienne
Kars
Fenwick
Van Koughnet
Deroche
Searchment
Whitman
Curtis
Hurlburt
Cuthbertson
Sturgeon
Rioux
Hodgins
Garden
Goulais Bay
Pennefather
Awores
Jarvis
Anderson
Chesley
Gillmor
Kane
Shing-wauk
Dagle
Wage
Duncan
Prince
Korah
Kehoe
Garden River
Echo
Mc Mahon
Morin
Otter
Jackson
Wakomata
Galbraith
SAULT STE. MARIE

LOCATION MAP Scale: 1:1 548 000 or 1 inch to 25 miles

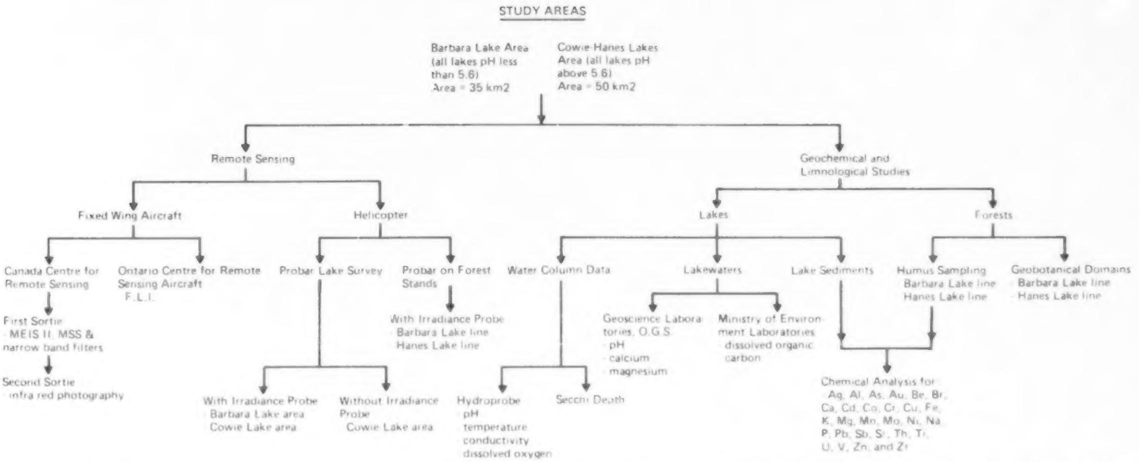
STUDY AREAS
Barbara Lake Area (all lakes pH less than 5.6) Area = 35 km2
Cowie-Hanes Lakes Area (all lakes pH above 5.6) Area = 50 km2
Remote Sensing
Geochemical and Limnological Studies
Fixed Wing Aircraft
Helicopter
Lakes
Forests
Canada Centre for Remote Sensing
Ontario Centre for Remote Sensing Aircraft F.L.I.
Probar Lake Survey
Probar on Forest Stands
Water Column Data
Lakewaters
Lake Sediments
Humus Sampling - Barbara Lake line - Hanes Lake line
Geobotanical Domains - Barbara Lake line - Hanes Lake line
First Sortie - MEIS II, MSS & narrow band filters
Second Sortie - infra red photography
With Irradiance Probe - Barbara Lake line - Hanes Lake line
Geoscience Laboratories, O.G.S. - pH - calcium - magnesium
Ministry of Environment Laboratories - dissolved organic carbon
With Irradiance Probe - Barbara Lake area - Cowie Lake area
Without Irradiance Probe - Cowie Lake area
Hydroprobe - pH - temperature - conductivity - dissolved oxygen
Secchi Depth
Chemical Analysis for: Ag, Al, As, Au, Be, Br, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Ni, Na, P, Pb, Sb, Sr, Th, Ti, U, V, Zn, and Zr

Figure 1. *Field and remote sensing methods used in the Barbara Lake and Cowie Lake studies. (Project 37.)*

Because of the many unknown factors involved in the relationship between acid lakes (and the forests that surround them) and data from remote sensing technologies, a broad approach to the solution of the problem has been adopted. More specifically, a mix of fieldwork and remote sensing from different platforms has been used to obtain a wide variety of data sets during the 1984 and 1985 field programs. In 1984 the remote sensing program included data collection from helicopter and fixed wing aircraft platforms as well as study of Landsat Thematic Mapper (TM) satellite imagery (Fortescue and Diamond 1984). The 1984 study also included the collection of field data from 113 lake sampling sites in 4 days. A preliminary interpretation of the remote sensing data sets obtained from this study is described by Fortescue and Singhroy (in press).

Because of the importance of verification of relationships between limnological and remote sensing data and the need for a control set of normal lakes with a pH greater than 5.6 the 1985 field work was focused: (1) in the vicinity of Barbara Lake where all lakes are known to be acid and (2) in the vicinity of Hanes Lake (Cowie Lake area) where all the lakes are normal. These two test areas are located some 32 km apart (Location Map).

OBJECTIVES

The objectives of the study were:

(1) To identify and sample two small study areas, one with acid lakes (i.e. pH of less than 5.6) and the other where lakes are normal pH (i.e. greater than 5.6) in order to obtain geochemical and limnological data from each lake for use in the interpretation of the remote sensing data.

(2) To obtain remote sensing data sets from helicopter, fixed wing, and satellite borne sensors (and cameras) for the identification of lakes which are acid and, particularly, those which are acid and clear.

(3) To provide an overview of the progress made during the 1984 and 1985 Remote Sensing/Geochemical projects and assess the role remote sensing data can play in planning future regional geochemical surveys in the Canadian Shield designed for mineral resource appraisal and/or acid rain study.

METHODOLOGY

An overview of the organization of the field and remote sensing studies is provided in Figure 1. Briefly, a total of 42 sample points were included in the Barbara Lake test area and 22 in the Hanes Lake site. The 66 sample sites were visited on September 10 or 11, 1985 for the purpose of limnological and geochemical data and sample collection.

Radiometer measurements from the helicopter were made on September 6 and 7 using a programmable radiometer (Probar®). A total of 50 lake sites in the Barbara Lake area and 50 sites in the Hanes Lake (Cowie Lake) area were included in this program which extended beyond the limits of the field test areas. In addition the programmable radiometer was used experimentally to collect data along two cut lines from which humus samples were collected, one at Barbara Lake and the other at Hanes Lake. This work was carried out at two different altitudes. An irradiance probe was used for all Probar® measurements except for a duplicate set obtained from the Hanes Lake area designed to investigate its effectiveness when used in a helicopter.

Fixed-wing aircraft measurements were carried out using a Fluorescence Line Imager (FLI®) in the spectral mode on August 31, 1985 using the aircraft of the Ontario Centre for Remote Sensing. On September 12 and 13 the areas were flown using the Multi-Detector Electro-Optical Imaging Scanner (MEIS II) to obtain narrow band, Multi Spectral Scanner (MSS) and Thematic Mapper (TM) simulated data sets from 20 000 feet. This instrument was mounted in the aircraft of the Canada Centre for Remote Sensing in Ottawa which also took infrared photographs of the Barbara and Cowie Lake areas from an altitude of 7000 feet. The availability of Landsat Thematic Map-

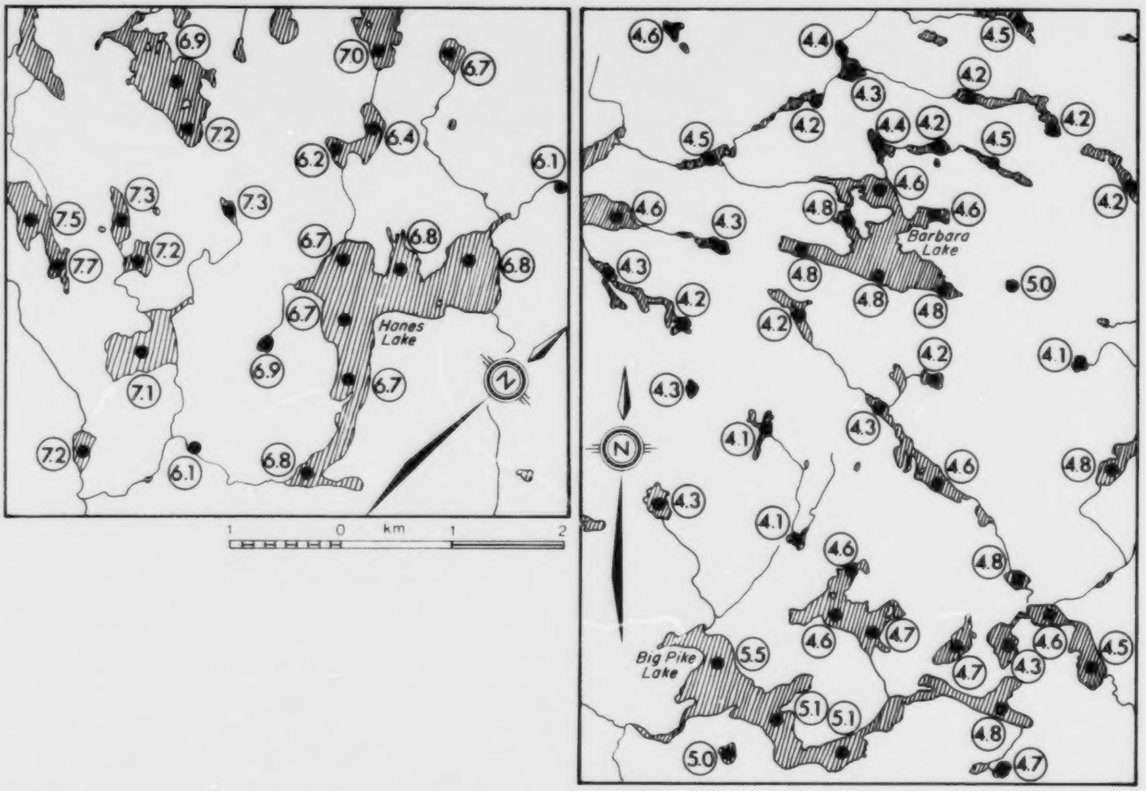

Figure 2. *Values for pH of surface lake waters as measured by the hydroprobe, Barbara and Hanes Lake areas. (Project 37.)*

per (TM) data for the August/September 1985 time window has not been established at the time of writing.

The geochemical and limnological work involved the study of lakes and the routine study of vegetation on an experimental basis. The study of lakes involved Hydroprobe® measurements of pH, temperature, conductivity, and dissolved oxygen in lake water columns, Secchi disc measurements, and the collection of water and sediment samples from each point. The water samples were used for confirmatory pH measurements in the Geoscience Laboratories of the Ontario Geological Survey in Toronto and for the estimation of levels of calcium and magnesium in them. Dissolved organic carbon (DOC) measurements on the water samples were made at the Ontario Ministry of the Environment Laboratories in Toronto. The lake sediment samples, together with samples of humus collected along the two cut lines, were prepared for determination of 28 elements using multielement methodologies under contract (Figure 1).

The data sets collected during 1985, together with those collected during 1984 from Raaflaub Township, will be interpreted during the winter months in order to establish reliable relationships between the limnology and geochemistry of clear lakes known to be acid and data from remote sensing.

PRELIMINARY RESULTS

On Figure 2, maps are provided to show the pH of lakes in the Barbara Lake and Hanes Lake areas as measured by the Hydroprobe® on September 10 or 11, 1985. It should be noted that the Hydroprobe® used was specially modified for use in lakes with low conductivity and pH, and lakes from both the Barbara Lake area and Hanes Lake area were measured on the same day with the same calibration of the Hydroprobe® to verify the performance of the instrument in the pH range from below 5.0 to over 7.0 during the same helicopter sortie.

Figure 2 provides an introduction to the interpretive activity which will take place over the winter months. In the Barbara Lake test area all lakes are seen to be acid with a pH of less than 5.6. In contrast all the lakes in the Hanes Lake area have a normal pH. A detailed examination of Figure 2 reveals the type of pH variation frequently found in areas of acid, or normal, lakes. It should be noted that a distinction cannot be made between clear and humic acid lakes on the basis of pH alone.

FUTURE WORK

The project provided some 40 sets of limnological and geochemical data for each lake studied in the two areas. In addition the remote sensing provided detailed spectral and air photographic data for the Barbara Lake and Hanes Lake areas observed on the ground. During the winter these data sets will be interpreted to discover a valid and reliable relationship between the remote sensing and field data. The results of this research will be reported later as a broadsheet focusing on the highlights of the results as they pertain to the recognition of clear acid lakes.

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38. A Regional Geochemical Study of Michipicoten Island

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[2]Geological Assistant, Geophysics/Geochemistry Section, Ontario Geological Survey.

INTRODUCTION

During a four-day period in late August 1985 a regional geochemical survey was completed of Michipicoten Island. The study involved the collection of lakewater and sediment samples from 94 locations in lakes and ponds on the island. The methodology used was designed primarily for mineral resource appraisal and also included an environmental (acid rain) component. As a result of a preliminary interpretation of the field limnological data, duplicate sediment cores from each of six locations were collected for further study. The study was one of a series designed to develop a technique of regional geochemical surveying suitable for conditions in the Precambrian Shield of Ontario.

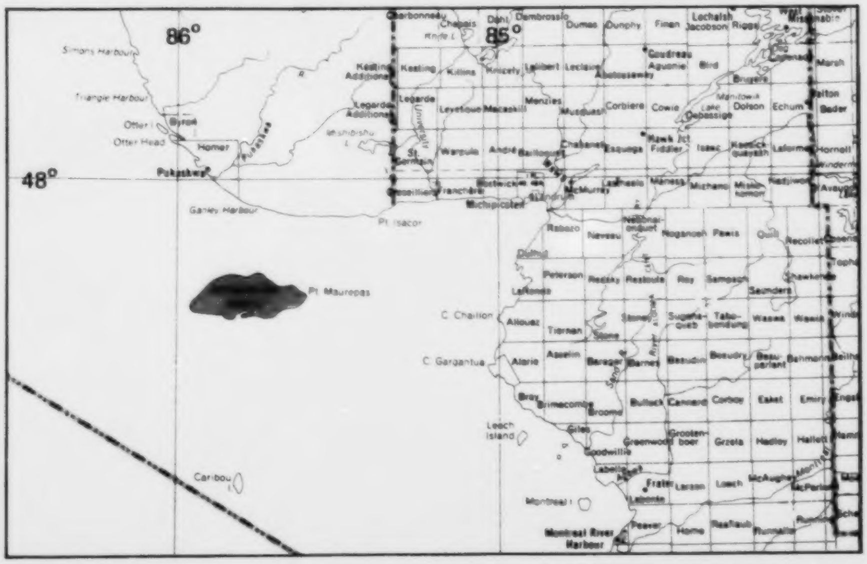
THE GEOLOGY OF MICHIPICOTEN ISLAND

Michipicoten Island is located in the northeastern corner of Lake Superior some 16 km south of the shore of the lake (Location Map) and is 184 km^2 in area. The geology of the island was described by Annells (1974) from which this account is derived. Briefly, the island is of interest geologically because it is an area of almost unmetamorphosed Neohelikian volcanic rocks situated at the eastern end of the south dipping northern limb of the Lake Superior syncline. More specifically, lava flows and intrusions of the Middle and Upper series of the Keweenawan Group make up almost all of the 4230 m succession on the island. The lavas account for up to 2460 m of this thickness, the remainder comprising intrusions and minor amounts of volcaniclastic and sedimentary horizons. The flows divide naturally into the Mamainse Point Formation, consisting of olivine-bearing flood basalts with minor intercalations of volcaniclastic rocks and coarse red-brown conglomerates, and the Michipicoten Island Formation of glassy andesites with some olivine-free basalt, rhyolite, volcaniclastic horizons, and fine-grained sediments.

Sills and domes of acid quartz porphyry and felsite (First Intrusive Phase) intruded the Mamainse Point Formation and these intrusions were in turn injected by large volumes of basaltic andesite (Second Intrusive Phase) which differentiated locally into granophyre. The time interval of the First Intrusive Phase overlapped that of the second.

The economic geology of Michipicoten Island was also discussed by Annells (1974) who noted that nearly all of the scattered copper deposits and showings occur in the Mamainse Point Formation rocks on the northern and western shores of the island. The copper deposits are of two types: stratiform bodies of Michigan type occurring in zones of amygdaloidal Quebec Mine basalt, conglomerate, or ash; and in thin quartz-calcite veins trending parallel and transverse to the strike of the flows.

As an area for a test regional geochemical survey based on lake and pond waters and sediments, Michipicoten Island has the advantage of a simple economic geological potential. The disadvantage of the island as a test area for regional geochemistry is the complexity of the lithology as just described which is accompanied by complex structural geology. This is a disadvantage because few drainage basins are underlain by a single rock type.


86°
85°
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Simons Harbour
Triangle Harbour
Otter I.
Otter Head
Byron
Homer
Pukaskwa
Ganey Harbour
Pt. Isacor
Pt. Maurepas
C. Chaillon
C. Gargantua
Leach Island
Caribou I.
Montreal I.
Montreal River Harbour
Keating Additional
Keating
Legarde Additional
Legarde
Mishibishu L.
St. Germain
Charbonneau
Chabois
Dahl
Dembrossio
Dumas
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Finan
Lochalsh
Jacobson
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Lalibert
Leclaire
Abotossaway
Goudreau
Aguonie
Bird
Brugels
Levesque
Macaskill
Menzies
Musquash
Corbiere
Cowie
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Dolson
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Wargula
André
Chabanel
Esquega
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Fiddler
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Lalibert
Laforme
Hornell
Franchère
McMurray
Lapheslo
Michano
Michipicoten
Rabazo
Naveau
Noganosh
Peever
Dolfus
Peterson
Rabsky
Restoule
Roy
Sampson
Saunders
Allouez
Tiernan
Stone
Sugawa-queb
Tabo-bondung
Wawa
Alarie
Asselin
Beaudin
Beaudry
Beau-parlant
Bray
Brimecombe
Broome
Bullock
Cannard
Corboy
Eaket
Emiry
Giles
Greenwood
Grooten-boer
Grzela
Hadley
Hallett
Goodwillie
Labelle
Fraser
Larson
Loach
McAughey
McParland
Labonte
Peever
Home
Raaflaub
Runnalls

LOCATION MAP Scale: 1:1 548 000 or 1 inch to 25 miles

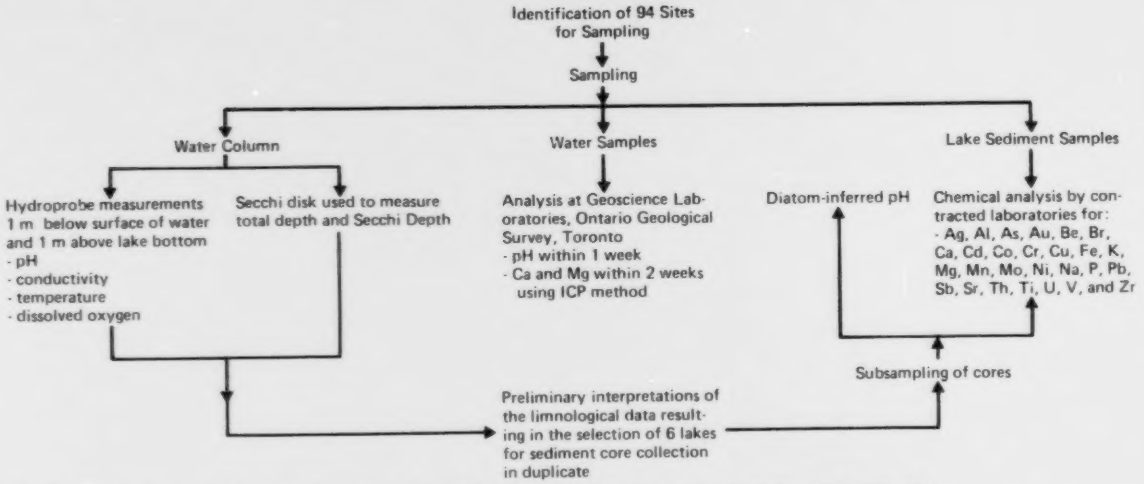
Identification of 94 Sites for Sampling
Sampling
Water Column
Water Samples
Lake Sediment Samples
Hydroprobe measurements 1 m below surface of water and 1 m above lake bottom
- pH
- conductivity
- temperature
- dissolved oxygen
Secchi disk used to measure total depth and Secchi Depth
Analysis at Geoscience Laboratories, Ontario Geological Survey, Toronto
- pH within 1 week
- Ca and Mg within 2 weeks using ICP method
Diatom-inferred pH
Chemical analysis by contracted laboratories for:
- Ag, Al, As, Au, Be, Br, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Ni, Na, P, Pb, Sb, Sr, Th, Ti, U, V, and Zr
Subsampling of cores
Preliminary interpretations of the limnological data resulting in the selection of 6 lakes for sediment core collection in duplicate

***Figure 1.** Field and laboratory methods used in the Michipicoten Island study. (Project 38.)*

In contrast, as a test site for environmental geochemistry (acid rain), Michipicoten Island provides an interesting challenge. Although subject to disturbance by man prior to 1900 during mining activities, since then the island has remained relatively undisturbed. It is of interest in the acid rain problem because it lies in the path of air masses from the southwest which are reputed to carry acid rain, and might be expected to intercept them, especially on the highlands of the island. Consequently for the environmentalist the pH of lakes and ponds on Michipicoten Island is of considerable interest. The stimulation of this interest is a good example of the usefulness of the regional geochemical survey for environmental as well as mineral resource appraisal purposes.

OBJECTIVES

The objectives of this survey are:

(1) To carry out a mineral resource regional geochemical survey of Michipicoten Island based on the sampling of lake and pond waters and sediments which include an environmental (acid rain) component

(2) On the basis of the limnological information obtained during the regional geochemical survey, to select a series of sample sites for collection of lake (or pond) sediment cores suitable for diatom-inferred pH and geochemical stratigraphic measurements to provide further environmental information

(3) To prepare a series of some 40 maps, each describing a single parameter measured at each of the 94 lake and pond sites sampled, and to provide a preliminary interpretation of the patterns on the maps so obtained with respect to mineral resource appraisal and environmental applications of the data.

METHODOLOGY

Prior to the commencement of the survey 94 sample sites were identified in lakes and ponds of Michipicoten Island on an airphoto mosaic at a scale of 1:15 840. Using a crew of three and a float-equipped A-star helicopter, sampling was conducted using an average of 9 minutes flying time per site, making a total of some 14 hours for the project to which was added the ferry time to the mainland for each sortie.

The methodology adopted for the Michipicoten Island regional geochemical survey is summarized on Figure 1. Briefly, a Hydroprobe® instrument was used to obtain onsite limnological measurements of pH, conductivity, temperature, and dissolved oxygen at one, or more, levels in the water column depending on conditions. A Secchi disk was also let down at each site to obtain the 'Secchi Depth' as well as the depth of the water column. At each site two samples were collected for transport to the Geoscience Laboratories, Ontario Geological Survey, Toronto. One was a water sample which was collected in a 1 litre bottle and kept cool for the journey after which pH, calcium, and magnesium were determined within it. The second sample was sediment taken with a gravity corer. At Michipicoten Island core samples were obtained relatively easily from the lakes which were relatively acid or large. In small beaver ponds there was often a lack of sediment owing to the relatively small time that the pond had been in existence. The sediment samples were taken in 1 litre plastic bottles which were decanted after 12 hours. The resulting sediment material was weighed wet into each of two 16 ounce vials and kept cool prior to chemical analysis after drying (Figure 1).

After the survey was completed the Hydroprobe® data sets were plotted and interpreted to provide a series of 6 lakes suitable for diatom-inferred pH measurements designed to provide a pH history for lakes and ponds at Michipicoten Island. The chosen lakes were then revisited and duplicate sediment cores collected from each one. After subsampling into seg-

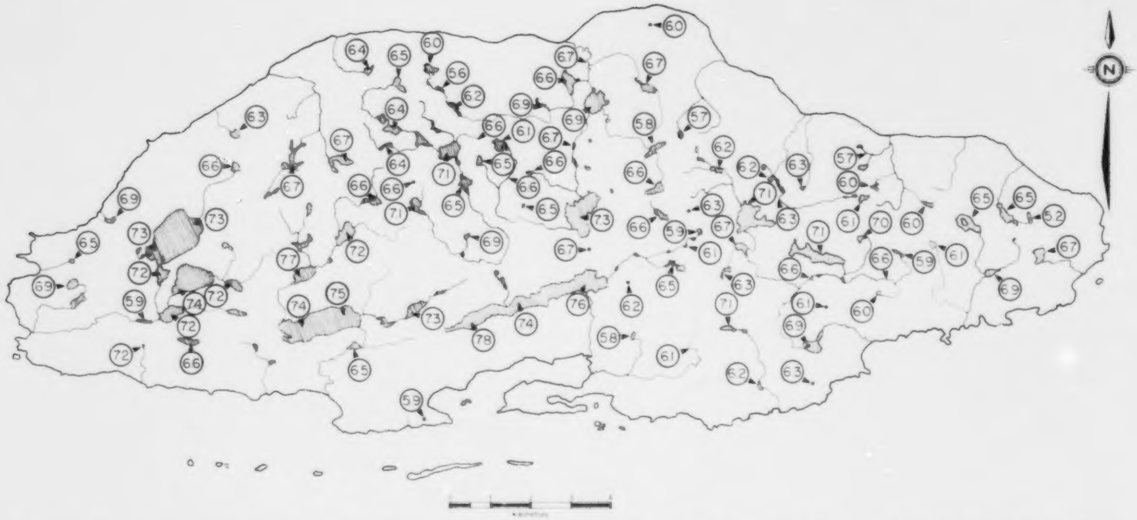

Figure 2. Map of Michipicoten Island showing the pH of lakes and ponds included in the regional geochemical survey completed during August 1985. (Project 38.)

ments each of these cores will be subjected to chemical analysis and, if warranted, diatom-inferred pH analysis.

The geochemical data for the waters and lake sediments will be transformed into Clarke units using the Clarke Index-I transform as described elsewhere (Fortescue 1985). The geology and topography of Michipicoten Island at a scale of 1:50 000, overprinted with the lake sediment sample point locations, will be incorporated into a broadsheet which also displays maps showing the geochemical patterns, element by element, plus the environmental information. The data sets used for map plotting will be printed on the reverse of the broadsheet.

PRELIMINARY RESULTS

On Figure 2 the pH of waters at each of the 94 sampling points included in the geochemical survey are listed. The patterns displayed were unexpected for two reasons. First, because very few of the waters were found to have a pH less than 6.0 and second because, with a few exceptions, the pH of waters tended to be more acid in the northeast of the island compared with the southwest. From the viewpoint of a geochemical survey of the type described here the identification of the existence of a pH pattern such as that described for Michipicoten Island in 1985 justifies the environmental component of the study. The explanation of patterns of this type clearly requires input by limnologists and other environmental scientists who are able to explain and solve problems of this type once they are identified.

SUMMARY

A test regional geochemical survey including an environmental (acid rain) component has been completed at Michipicoten Island. The survey demonstrated the rapidity at which a survey of this type can be completed and the complexity of the observation package which can be applied during a brief visit to a lake sampling site. The pH map (Figure 2) indicated how the data from a geochemical survey of this type can be of direct interest to environmentalists because it brings into focus problem areas which were previously unknown.

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MINERAL DEPOSITS PROGRAMS

Summary of Activities 1985, Mineral Deposits Section

A.C. Colvine

Section Chief, Mineral Deposits Section, Ontario Geological Survey.

The program of the Mineral Deposits Section proceeded in the direction, and roughly on the schedule, outlined previously (Colvine 1983, 1984). The available resources continued to be devoted principally to thorough field based studies of mines or areas of high potential for mineralization. While gold studies continued to be the principal emphasis of the program, the intended diversification has become evident this year. Detailed project descriptions and progress, and funding sources are contained in individual reports.

In the gold program, the increasing database on areas of known gold deposits, which has been generated from the work of this group and others over the last four years, was used to prepare a synthesis of the geological associations of gold mineralization in order to provide rational guidelines for further exploration (Colvine *et al.* 1984). This work provided an enhanced ability to determine the relative importance and significance of the overall geological characteristics of a gold camp; from that it was possible to target geologically favourable areas for further project work and provide a degree of predictability as to the expected styles of mineralization, alteration, lithological and structural controls, and other important characteristics. Much of the new project work of the Section is devoted to documentation of these features in areas of limited historical production. Some of these projects are being carried out as part of multi-component interdisciplinary geoscience programs.

Projects were initiated or continued in several parts of the Province to better document the geological characteristics outlined above. These are as follows: detailed mapping of selected areas of the northwestern portion of the North Caribou Lake belt (Piroshco and Shields, Project S55); detailed mapping of the geological setting of the Duport Mine, Shoal Lake (Smith, 42); detailed mapping around the Moss Mine, Shebandowan Belt (Chorlton, S43) and select reexamination of occurrences (Brown, S44); regional and detailed mapping around mineralization at Mishibishu Lake (Heather, S15); detailed mapping in Harker and Holloway Townships (Whittaker, S59) and detailed studies of other deposits in the Black River-Matheson area (Troop, S61; Malczak, S60). Rather than focussing on detailed mapping, the new project in the Confederation-Uchi Lakes area (Fyon and Lane, S41) was of a regional reconnaissance scale in order to add structural and alteration data to the well established lithostratigraphic data base; deformation zones and alteration are considered an essential component of the gold system (Colvine *et al.* 1984).

Projects reported previously in areas encompassing large known gold deposits were either continued or neared completion: the multidisciplinary studies in the Red Lake area (Andrews and Lavigne 1984) were brought to an advanced stage with detailed mapping in the Campbell and Dickenson mines (Andrews and Hugon, 40) prior to final report preparation; several studies in the Geraldton-Beardmore belt (Mason and Macdonald 1983, Buck and Williams 1984) are being prepared for release as individual reports and will form the basis for a comprehensive report of the Geraldton Gold Camp being coordinated by A.J. Macdonald; several individual studies in the Abitibi Belt are nearing completion (Cherry 1984); in the second year of the study of the Detour Lake Mine (Soussan Marmont, 45) detailed mapping of all available outcrops in the area encompassing the deposit was conducted, with the intent of broadening the coverage of the Belt in the third year.

In an attempt to provide new data on the occurrence of Platinum Group Metals a detailed mapping project of mineralization at Lac des Iles was initiated (Macdonald, 46) to complement the ongoing work of the Precambrian Section (Sutcliffe, 8).

Further work on the gold potential of the Huronian Supergroup focussed on detailed mapping of the Western Cobalt embayment (Long and Colvine, 47). The depositional environment of the Lorrain Formation was better defined and anomalous gold concentration was recognized within one of the units of the Formation. A preliminary map of portions of a fourteen Township area is in preparation. Reports on previous years work are being prepared for publication.

The exciting opportunities in the field of industrial minerals are becoming increasingly recognized. The Section is attempting to develop a working group to provide new data which will aid evaluation of the economic potential of these commodities. The immense diversity of raw materials and usages both dictates the approach to this work and necessitates focussing of efforts on specific commodities. Determination of suitability of specific raw materials requires comprehensive testing in contrast to more simple assay procedures used in evaluation of metallic deposits.

Specific projects underway include: testing of alaskites as potential raw material sources for ceramics (Vos, 48); geological mapping of clays and shales, and sampling and ceramics testing of individual occurrences and mixes (Martini and Kwong, 49); examination and recovery testing of graphite (Springer, 51); examination and testing of vermiculite occurrences for the range of existing and new usages for this commodity (Mackinnon *et al.* 52); examination of the building stone potential in Southern Ontario (Verschuren, 53); and a multidisciplinary study of the Paleozoic unconformity in Southern Ontario as a potential source of pigment and gold specimens (Springer, 50). In addition, the industrial mineral potential of the Black River-Matheson area was examined (Malczak, S62). Not reported at this stage is preliminary work by J. Springer to evaluate the occurrence and use of celestite in the manufacturing of pure strontium carbonate.

While it is hoped that these projects provide useful data, they only scratch the surface of a diverse and complex geo-industrial entity—industrial minerals.

The effort to communicate the products of this work continued through public presentations and publications. Innumerable talks and displays were presented at various centres throughout Ontario and selected centres in North America. The group presented several papers at a special Archean gold session at the GSA/SEG Meeting at Reno, Nevada in 1984 in order to promote new exploration for gold in Ontario.

Listed below are the publications released by the Mineral Deposits Section over the last year:

1. Ontario Mineral Map; Map 2472.
2. Pre-Engineering Feasibility Study of a Limestone Crushing Facility in Northern Ontario; Open File Report 5523.
3. An Integrated Model for the Origin of Archean Lode Gold Deposits; Open File Report 5524.
4. Silica Markets and Uses in Northern Ontario; Open File Report 5526
5. The Geology of Selected Gold Deposits in Anglesea, Barrie and Clarendon Townships, Southeastern Ontario; Open File Report 5528.
6. Gold-Quartz-Arsenopyrite Vein Deposits Localized near the Base of the Flinton Group, Kaladar and Barrie Townships, Southeastern Ontario, Open File Report 5529.
7. Talc in the Tudor Formation, Grenville Supracrustal Series, Southeastern Ontario; Open File Report 5530.
8. Geology and Mineral Deposits of Lundy Township, Timiskaming District, Map P.2733.
9. Field Guide to the Beardmore-Geraldton Metasedimentary Metavolcanic Belt (42H/12); Open File Report 5538.
10. Property Visits and Reports of the Atikokan Economic Geologist, 1979-1983, Atikokan Geological Survey, Open File Report 5539.
11. Base Metal, Molybdenum and Precious Metal Deposits of the Madoc-Sharbot Lake Area, Southeastern Ontario, Open File Report 5548.
12. Base Metal, Molybdenum and Precious Metal Deposits of the Madoc-Sharbot Lake Area, Southeastern Ontario, Southern Ontario (31C), Map P. 2737.
13. An Annotated Bibliography of the Platinum Group Elements, Open File Report 5559.
14. Lime Resources of the Thunder Bay Area, Open File Report 5566.

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Colvine, A.C., Andrews, A.J., Cherry, M.E., Durocher, M.E., Fyon, A.J., Lavigne, M.J., Jr., Macdonald, A.J., Marmont, Soussan, Poulsen, K.H., Springer, J.S., and Troop, D.G.
1984: An Integrated Model for the Origin of Archean Lode Gold Deposits; Ontario Geological Survey Open File Report 5524, 98p., 7 tables, 53 figures, and 2 appendices.

Mason, J.K., and Macdonald, A. James.
1983: Mining and Exploration Activities and Gold Studies in the Beardmore-Geralton Belt; p.191-193 *in* Summary of Field Work 1983, by the Ontario Geological Survey, edited by John Wood, Owen L. White, R.B. Barlow and A.C. Colvine, Ontario Geological Survey Miscellaneous Paper 116, 313p.

40. Alteration, Metamorphism, and Structure Associated with Archean Volcanic-Hosted Gold Deposits, Red Lake District; Studies in the Campbell and A.W. White Mines

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[1]Geologist, Mineral Deposits Section, Ontario Geological Survey, Toronto.

[2]Post Doctoral Fellow, University of Toronto.

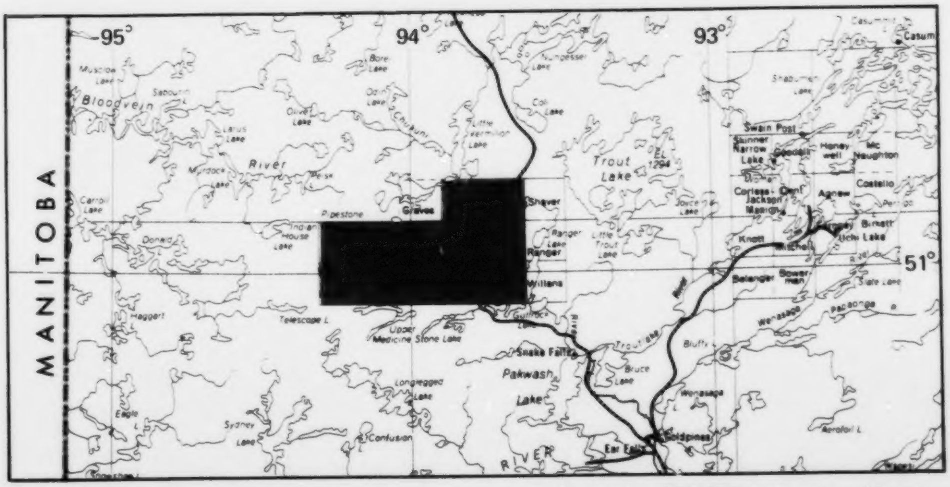
INTRODUCTION

The Red Lake gold project was initiated in 1982 for the purpose of examining the nature and history of alteration, metamorphic, and structural processes which have affected the Red Lake greenstone belt, and how they relate to the gold mineralization which occurs in the area (Andrews and Lavigne 1984). During the 1985 field season studies were conducted in selected areas of the Campbell Red Lake and A.W. White (formerly Dickenson) Mines. This involved a cooperative effort between A.J. Andrews and H. Hugon (the latter under the auspices of the Ontario Geoscience Research Fund) and represents the final stage of a longterm, multidisciplinary study of the Red Lake gold district.

As revealed in previous stages of the Red Lake project, the eastern section of the Red Lake belt is characterized by the occurrence of regional scale deformation zones (Hugon and Schwerdtner, in press) and an extensive contact thermal aureole surrounding the Trout Lake batholith located to the northeast (Andrews 1984). As defined by Hugon and Schwerdtner (in press) the deformation zones form a belt-wide, conjugate system of large-scale structures which were generated during the emplacement of the surrounding batholiths. The Campbell and A.W. White Mines are located within the northwest-southeast trending Cochenour-Gullrock Lake deformation zone, and occur within the domain of the contact thermal aureole around the Trout Lake batholith. The mine workings immediately adjoin each other (Figure 1) and exploit a single complex system of ore bodies (hereafter referred to as the mine complex).

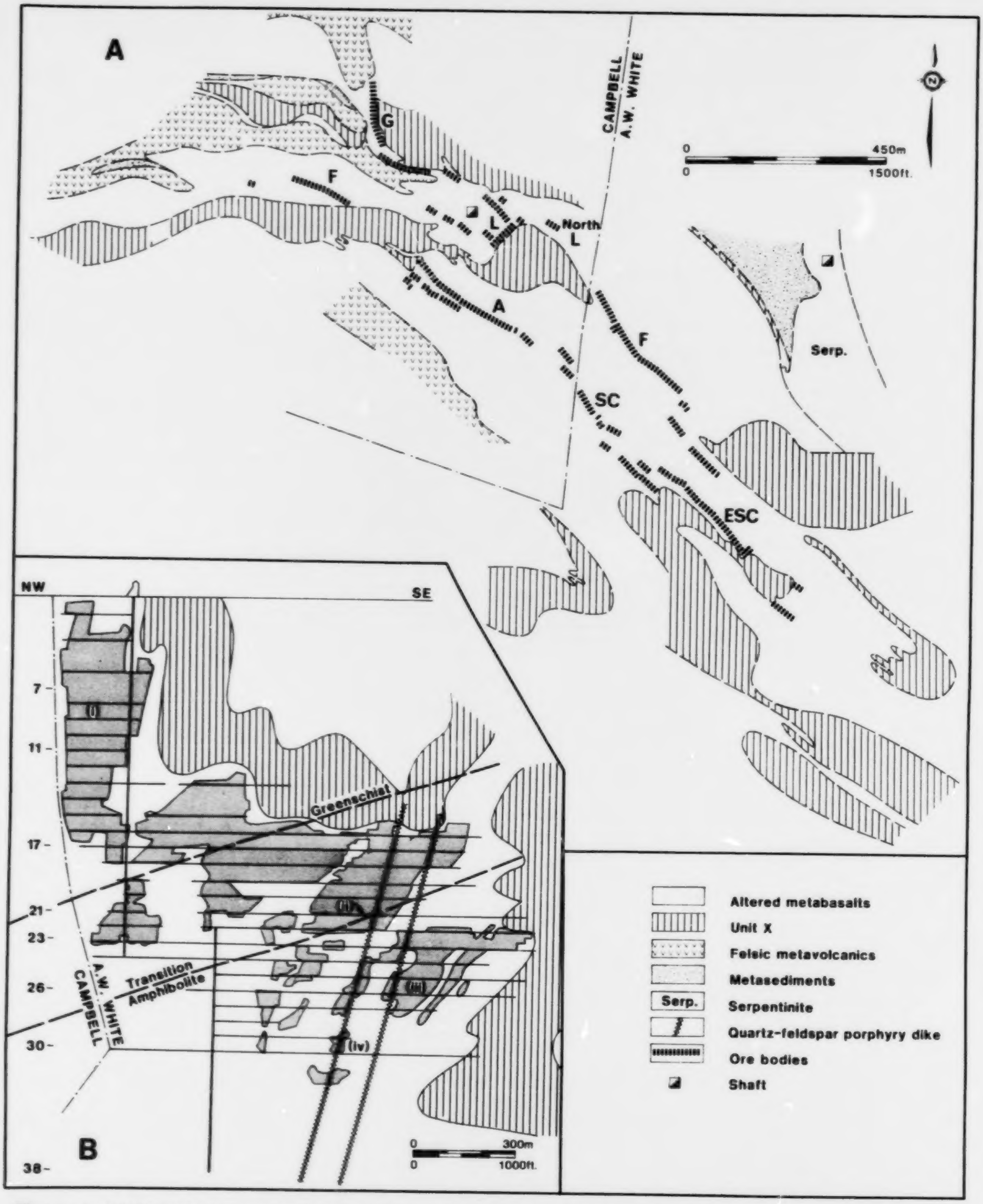
The purpose of this stage of the project is to define the main characteristics of gold mineralization in terms of alteration, structural, and metamorphic patterns in the immediate environment of the deposits, and to relate these to the more regional patterns established as a result of our previous work. Special emphasis is being given to investigating how the nature and form of ore bodies relate to local variations in alteration, structure, lithology, and metamorphic grade, and to determine details of the history of geological events which characterized the period(s) of mineralization.

Information available from previous studies conducted in selected parts of the Campbell and A.W. White Mines (e.g. Kusmirski and Crocket 1980; Rigg and Helmstaedt 1981; MacGeehan and Hodgson 1982; Lavigne and Crocket 1983; Mathieson and Hodgson 1984), featured prominently in the design and implementation of our mine studies, and will aid in the interpretation of the results. Our investigation involved geological sampling and documentation of essential features in selected, representative areas of both mines. In the A.W. White Mine most of our work was conducted on the 7, 11, 21, 26, and 30 levels, with more site specific studies carried out on the 16, 17, and 23 levels. In the Campbell Mine, the main work was carried out on the 8, 16, and 27 levels with site specific work performed on the 4 and 11 levels. The following summarizes our preliminary observations and conclusions.



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles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Unit X
Felsic metavolcanics
Metasediments
Serp.
Serpentinite
Quartz-feldspar porphyry dike
Ore bodies
Shaft

Figure 1. *(a) Simplified geological compilation of the 15 level, Campbell Red Lake and A.W. White Mines. For simplicity, dike systems have been omitted and 'acid lava' has been included with altered metabasalts (modified after 50' scale mine plans, A.W. White mine). (b) NW-SE longitudinal section through the SC-ESC ore zone of the A.W. White Mine, illustrating, on a preliminary basis, the location of the metamorphic isograd surfaces. Shaded areas indicate SC-ESC ore bodies as represented by stopes and ore reserve locations (modified from A.W. White Mine section). (Project 40.)*

LITHOLOGY

The main lithological types which characterize the mine complex have been described in previous studies (*op. cit.*), and are only briefly summarized here. Mafic metavolcanic sequences, most of which are pillowed, predominate in both mines, accompanied by subordinate quantities of fine-grained, felsic, probably extrusive rocks, occurring mainly in the Campbell workings, and a mineralogically and texturally heterogeneous rock type termed 'chickenfeed' in the A.W. White Mine and 'altered rock' in the Campbell Mine, hereafter referred to as unit X (Figure 1). A system of mafic to ultramafic dikes are widespread throughout both mine workings, and isolated, intermediate to felsic, quartz-feldspar porphyry dikes are restricted to the southwestern part of the A.W. White Mine.

The main hosts to gold mineralization are the mafic volcanic sequences and unit X. On the basis of pillow-like forms occurring in specific parts of the unit X rock type, together with a limited number of analyses revealing high chromium and nickel contents, previous workers (e.g. Kusmirski and Crocket 1980; MacGeehan and Hodgson 1982) have suggested that these units may have originated as ultramafic, extrusive-intrusive complexes. As described below, the contact areas of unit X have played a fundamental role in the localization of some of the richest orebodies in the mine workings. As such, a concerted effort will be made to mineralogically and structurally define this enigmatic rock type and its significance to ore deposition.

The combined effects of intense deformation and alteration preclude any meaningful attempt at stratigraphic reconstruction of the Campbell and A.W. White workings as a whole.

METAMORPHISM

Examination of hand specimens and a limited number of thin sections indicates that definite systematic changes occur in mineralogy and crystallinity of the mafic pillow basalts, proceeding from west to east and with depth in the mine complex. This manifests as a transition from predominantly fine-grained, highly altered (silicified and carbonatized) material dominating in most of the existing Campbell workings and the western section of the A.W. White Mine, to a more crystalline, alumino-silicate-bearing material in the lower southeastern workings of the A.W. White Mine. While garnetiferous mafic units occur sporadically throughout the mine complex, there is a noticeable increase in both the size and the abundance of garnets with depth and to the southeast. Thin section examination of mafic pillow basalts from the upper levels (7,11, and 16) in the western section of the A.W. White Mine reveals a fine-grained assemblage consisting mainly of quartz, biotite, Fe-carbonate, chlorite, and white mica. In contrast, mafic pillow basalts located in the southwestern sections of the 26 and 30 levels of this mine exhibit a complex assemblage of metamorphic minerals including chlorite, quartz, biotite, chloritoid, garnet, staurolite, cordierite, and andalusite, plus additional silicates, which as yet have not been firmly identified. Garnet occurs primarily as porphyroblasts, while most of the other minerals form part of the fine- to medium-grained matrix.

On the basis of the distribution and size of garnet porphyroblasts, and the occurrence of distinctive metamorphic minerals, it is suggested that the Campbell and A.W. White Mine workings are transected by a metamorphic isograd surface dipping approximately west to southwest (Figure 1b), defining a transition from greenschist to amphibolite grade. This is interpreted to represent part of the regional, metamorphic thermal aureole developed around the Trout Lake batholith (Figure 1, Andraws 1984).

ALTERATION

Alteration in the Campbell and A.W. White Mines can be discussed in terms of that which occurs on a mine scale (kilometres), and that which is specific to the local environments of individual orebodies (centimetres to metres). Alteration phenomena of an intermediate scale, that is, relating to systems or groupings of individual ore bodies is not so far evident. Thus the volume ratio of altered rocks to orebodies is very large indeed.

MINE SCALE

Alteration is widespread and pervasive in all lithologies throughout the mine complex, with the possible exception of the late systems of mafic to ultramafic dikes. This alteration forms a small part of the highly altered zone (HAZ), which extends from the immediate vicinity of the A.W. White and Campbell Mines, northwest to include the general areas of the Cochenour, Marcus, and McMarmac Mines, and finally dissipates beneath the main body of Red Lake (Figure 1, Andrews 1984). This broad domain of alteration is coincident with one section of the Cochenour-Gullrock Lake deformation zone.

As is typical for the HAZ as a whole, alteration of mafic lithologies within the mine complex is generally characterized by the scarcity to complete absence of amphibole (actinolite and hornblende) and plagioclase, minerals which are typically present in the surrounding country rocks. On the greenschist side of the isograd, alteration of mafic precursors appears to have involved widespread silicification and Fe-carbonatization similar to that which characterizes the HAZ to the northwest (Andrews 1984), and imparting an easily discernible greyish white to light brown colouration to the rocks. Within the amphibolite domain of the mine complex, the distinctive aluminosilicate-bearing mineralogy of mafic volcanic precursors, is in marked contrast with the hornblende-plagioclase-quartz assemblage which characterizes the surrounding country rocks. The most obvious megascopic feature which serves to distinguish between them, is the abundance of garnets in the former, relative to the general paucity of this mineral in the latter. Apart from this, the highly altered and unaltered amphibolite grade mafic rocks are similar in appearance, and the recognition of aluminosilicate-bearing assemblages in the altered equivalents requires petrographic analysis.

The presence of aluminosilicate assemblages within mafic volcanic precursors requires that the mine rocks experienced pervasive chemical alteration either prior to or coincidental with the peak of thermal metamorphism. The type of aluminosilicates developed (as described above), together with the occurrence of significant quantities of quartz in these rocks, suggest that alteration has involved widespread silicification either by a net input of SiO_2 and/or an increase in this component through residual enrichment. While carbonate veining (mainly Fe-carbonate and lesser calcite) is prolific within the mine complex as a whole, carbonate replacement is developed primarily within the greenschist domain and appears rare to non-existent in the amphibolite domain.

Superimposed on the mine scale alteration, various local alteration effects occur within the mafic lithologies, two of the most important of which are described here as (a) streaky silicification, and (b) carbonate replacement banding (the latter termed 'banded andesite' by Campbell geologists). Streaky silicification manifests as a patchy bleaching effect which is characterized mineralogically by the absence of garnet and a significant increase in modal percent quartz relative to that in the immediately surrounding areas. The bleached areas are typically lensoidal (centimetres to metres in dimension), and often coalesce to form areas of patchy bleaching, metres in width and probably tens to hundreds of metres in strike length. In many cases, it can be observed that the lensoidal form of this alteration is due to the selective replacement of pillows which are moderately to highly deformed. Streaky silicification occurs sporadically throughout the mine complex in both amphibolite and greenschist domains.

Carbonate replacement banding appears to be restricted to the greenschist domain and is most obviously developed in the upper levels of the Campbell workings. It is often observed in pillow basalts and manifests as closely spaced, 0.5 to 1.0 cm wide, parallel bands of Fe-carbonate replacement, which crosscut pillow selvages. The bands are elongate but discontinuous, and in some cases appear brecciated. In general the bands are aligned parallel to the main foliation.

At this time the relationship of streaky silicification and carbonate replacement banding, with respect to the widespread, mine scale alteration is not known. One possibility is that they were all formed as part of the same hydrothermal process (event), in which case the localized effects may simply represent zones of most intense alteration. It is significant that neither of the localized effects shows any special relationship to orebodies. In fact, in a number of locations orebodies are observed to crosscut and overprint them.

In different locations of the mine complex unit X may be described as massive amphibolite, chlorite schist, talc-carbonate schist, quartz-biotite schist, and Fe-carbonate-quartz rock. Most of these variations can occur across single 30 to 200 m cross-sections of unit X as exposed in the Campbell workings. In addition to the variability on a local scale, there is some evidence to suggest that systematic mineralogical changes may also occur on a mine scale. For example, there is some tendency for unit X to exhibit intense replacement by Fe-carbonate in the amphibolite domain (i.e. the southeastern workings of the A.W. White Mine), whereas it is more commonly chlorite-talc-carbonate or biotite schist in the greenschist domain (e.g. in the Campbell workings). It is hoped that follow up petrographic analysis will help to resolve many of the questions relating to the nature of unit X.

OREBODY SCALE

Vein type orebodies predominate in the mafic volcanic hosts and are characterized by narrow zones of wallrock alteration, usually a few centimetres, and sometimes up to a metre in width, on either side of the ore structure. The alteration is characterized by either strong biotite development, in which case a medium to dark brown colour is imparted to the wallrock, or silicification (often accompanied by variable amounts of fine-grained arsenopyrite), resulting in a whitish grey, bleached appearance. Along any given length of a vein structure, the wallrock alteration tends to be rather sporadically developed, alternating in a rather non-systematic way between biotitic development and silicification, and sometimes apparently disappearing altogether. The alteration tends to be least apparent where veins occur as single, bold structures greater than 0.5 m in width, and best developed where the structures dissipate into multiple, closely spaced, thin veinlet systems or arsenopyrite replacement bands. No obvious systematic changes were observed in the nature of vein wallrock alteration from amphibolite to greenschist domains.

Brown, biotitic alteration zones form haloes a few metres in thickness around the large arsenopyrite replacement type orebodies which characterize the G and L zones of the Campbell Mine (Figure 1a). These orebodies occur at the contact areas between unit X and mafic volcanic rocks, and are typically accompanied by intense silicification, which is intimately associated with the arsenopyrite replacement body itself, or impregnating large Fe-dolomite veins. Brown, biotitic alteration haloes a few centimetres in width typically envelope ore structures hosted within unit X. In "sheeted veinlet zones", a structural environment peculiar to unit X (described below), this alteration can be quite extensive, in some cases extending for metres in width and tens of metres in strike length, similar to, but somewhat more restricted than, the dimensions of the sheeted veinlet zones themselves.

In almost all cases, the wallrock alteration is accompanied by disseminated pyrite and lesser pyrrhotite. No obvious systematic changes were detected in the nature of wallrock alteration from greenschist to amphibolite domains in the mine complex as a whole.

ORE ENVIRONMENTS

CAMPBELL MINE

The known ore mineralization in the Campbell Mine may be described in terms of three main environments consisting of, (a) veins within mafic volcanic hosts; (b) veins and large replacement zones along mafic volcanic-unit X contact areas; and (c) replacement bands within unit X hosts. Additional environment types exist but tend to be subsidiary in occurrence, tonnage, and grade.

Environment type (a) consists of strike persistent Fe-carbonate-quartz veins, the main examples of which are the A-F and North L zones (Figure 1a). The vein systems have a very persistent northwest-southeast strike, and dip steeply to the southwest. While their orientation generally appears parallel to the main ductile fabric which characterizes both mine workings, in well exposed areas the veins are observed to be very slightly oblique to this fabric, both in strike and dip. The A-F and North L vein systems persist throughout the 21 working levels of the Campbell Mine, and it seems likely that further development will continue to expose them at greater depth. The morphology of the veins varies continuously along their strike length manifesting as strong single structures greater than 1 m in width; closely spaced parallel veins 1 to 2 m apart; weak stringer systems; and elongate bands (0.5 1.0 m in width) of fine-grained quartz-arsenopyrite replacement. The structures appear to have originated as banded Fe-carbonate veins which experienced deformation subsequent to their formation, causing internal brecciation and allowing for impregnation and replacement by fine-grained quartz and arsenopyrite. The introduced quartz and arsenopyrite form the matrix to carbonate vein breccias, dilate original carbonate banding, and partially replace the original carbonate material itself. Gold occurs exclusively within the introduced fine-grained quartz and arsenopyrite. The vein structures, are typically crosscut by white, coarser grained quartz and pyrrhotite ladder veins, which are barren. In general the North L vein tends to be more silicified than the A-F system, and the original carbonate material is less obvious.

The Fe-carbonate quartz vein systems are best developed within the mafic lithologies, but in some locations occur adjacent to or along unit X contacts, where these contacts subparallel or parallel the northwest-southeast trending ductile fabric.

Environment type (b) occurs where unit X contacts form rolls; that is, they abruptly change direction to form a moderate to high angle with the northwest-southeast trending ductile fabric, sometimes forming a local termination (in plan) to the unit X body itself. Best developed as the G and L zones (Figure 1a), the morphology of these ore systems are intimately related to that of the roll; that is, they form pipe- to sheet-like bodies limited in plan to the strike length of the roll, but relatively continuous with depth. Manifestations of the G and L zones occur throughout the 21 working levels, and are open to depth. Within this environment (Figure 2a), the orebodies occur in two main forms, (a) large, banded Fe-carbonate veins, usually metres in width and hosted by the mafic volcanic rocks, and (b) irregular areas of intense silicification and arsenopyrite impregnation, measuring tens of metres in horizontal dimension, pipe-like in vertical dimension, and hosted by both the mafic volcanic rocks and unit X. In close proximity to the roll contact, the Fe-carbonate veins typically parallel unit X; that is, they occur at a moderate to high angle to the northwest-southeast fabric. With distance from unit X they rapidly change orientation to a more westerly to northwesterly direction concomittant with rapidly decreasing ore grades (Figure 2a). The Fe-carbonate veins close to the roll are typically brecciated, and impregnated with fine-grained quartz and arsenopyrite. The more intense this disruption, the better the ore, with gold occurring exclusively within the introduced quartz and arsenopyrite. The areas of intense silicification and arsenopyrite impregnation occur adjacent to and surrounding the Fe-carbonate veins in the immediate area of the contact, hosted either by the mafic volcanic rocks and/or unit X. In part, they form the matrix filling to breccias of these host rocks. The more intense the replacement the better the ore. In both carbonate veins and replacement bodies, gold occurs exclusively with the fine-grained quartz and arsenopyrite. With increasing distance into unit X, the ore adopts a form of west to northwest trending, narrow, anastomosing replacement bands of fine-grained quartz and arsenopyrite. These are often hosted by sheeted veinlet systems (Figure 2a) and usually dissipate within 50 m of the roll contact. Within the mafic volcanic rocks beyond the immediate influence of the roll environment, ore structures revert back to fabric parallel, northwest-southeast trending quartz and iron carbonate-quartz veins.

Environment type (c) is observed primarily within 'sheeted veinlet zones', a structural phenomenon exclusive to unit X. These zones measure on the order of metres in width and tens of metres in strike length, consisting of an intense development of subparallel to parallel veins. The veins are predominantly Fe-carbonate with lesser calcite, usually a centimetre or less in width, and the same distance apart. The host rock is typically chlorite-talc-rich, becoming strongly biotitic in the vicinity of ore, as already described. The ore comprises narrow, replacement bands, usually a few centimetres to a metre in width, and consisting of fine-grained quartz and arsenopyrite. Within the ore bands, quartz and arsenopyrite replace both the sheeted veinlets and the chlorite-talc matrix of the host unit X. In different locations of the Campbell Mine, sheeted veinlet zones form strike extensions of, (1) type b ore environments within unit X (Figure 2a), and (2) Fe-carbonate-quartz vein systems, where these northwest-southeast structures obliquely crosscut the unit X bodies.

Disseminated pyrite and pyrrhotite typically occur within the immediate vicinity of all orebodies, but do not themselves constitute ore.

A.W. WHITE MINE

The known ore mineralization in the A.W. White Mine may be described in terms of two main environments consisting of, (a) veins and replacement bands within mafic (mainly volcanic) hosts, and (b) disseminated sulphide replacement bodies within mafic volcanic hosts.

Type (a) environments consist of veins and replacement bands which are similar to, and/or actually extensions of, the Campbell (environment type (a)) vein systems. The SC-ESC system of the A.W. White Mine is an extension of the A-F system of the Campbell Mine (Figure 1a). At the extreme western end of the A.W. White Mine (i on Figure 1b), the SC ore structure consists of an Fe-carbonate-quartz vein structure, which appears identical in all respects to that of the Campbell A-F zone as described above. However, proceeding eastwards from the SC to the ESC part of the system, there is a definite tendency for arsenopyrite and quartz to increase at the expense of Fe-carbonate, and for the ore form to change from a bonafide dilatent vein filling to a linear band of arsenopyrite and quartz replacement. This situation is illustrated by the form of this ore structure as observed in the 22-878 No. 8 stope, and along the east drives of the 26 and 30 levels (respectively ii, iii, and iv on Figure 1b). In the 22-878 No. 8 stope the ore structure, ranging from a few centimetres to a metre in width, alternates along its length from an internally brecciated quartz-iron carbonate vein (only a few ghosts of Fe-carbonate fragments visible) to a fine-grained quartz-arsenopyrite replacement band. One receives the impression that either dilatency was originally sporadic along this structure, or an original intact vein has been stretched and boudinaged. Gold occurs in association with quartz in the vein part of the ore structure, and with arsenopyrite where it manifests as a replacement band. Pyrite and lesser pyrrhotite occur as the matrix to quartz and arsenopyrite breccia, and disseminated within the wallrock, but does not constitute ore. On the 26 and 30 levels the ESC ore structure consists primarily of a fine-grained quartz-arsenopyrite replacement band exhibiting vein-like continuity, but with little evidence of actual dilatency. Small, irregular shaped pods and lenses of slightly coarser grained quartz, which occur sporadically along any given length of the replacement band, could represent either a replacement feature, a ladder vein structure, or a highly deformed segmented vein. Gold values occur within the fine-grained quartz-arsenopyrite replacement band, and visible gold occurs sporadically within the coarser quartz pods.

Type (b) environments comprise large zones of disseminated sulphide mineralization (mainly pyrite and lesser pyrrhotite) hosted within massive to pillowed mafic volcanic rocks. Within these zones the sulphides occur in closely spaced, discontinuous bands and irregular streaks a few millimetres in width, and generally parallel to subparallel with the northwest-southeast foliation. In plan the sulphide replacement zones form in lensoid shapes, tens of metres in dimension, and often in multiple arrays roughly aligned in a north-south direction (Figure 2b). The bulk of the gold occurs in intimate association with pyrite, although high grade pods of visible gold also occur in folded quartz stringer systems contained within the sulphide replacement zone. Fine-grained, arsenopyrite-quartz replacement bands typical of environment type (b) can occur sporadically within the sulphide zones or along their northwest-southeast trending strike extensions. At present, ore zones of the sulphide replacement type supply the bulk of the ore in the A.W. White Mine from stopes on the 26, 24, and 23 levels in the southeastern workings, and on the 11 and 7 levels closer to the Campbell Mine boundary. Orebodies of this type occur in the Campbell Mine (22 and 4 levels), but do not at

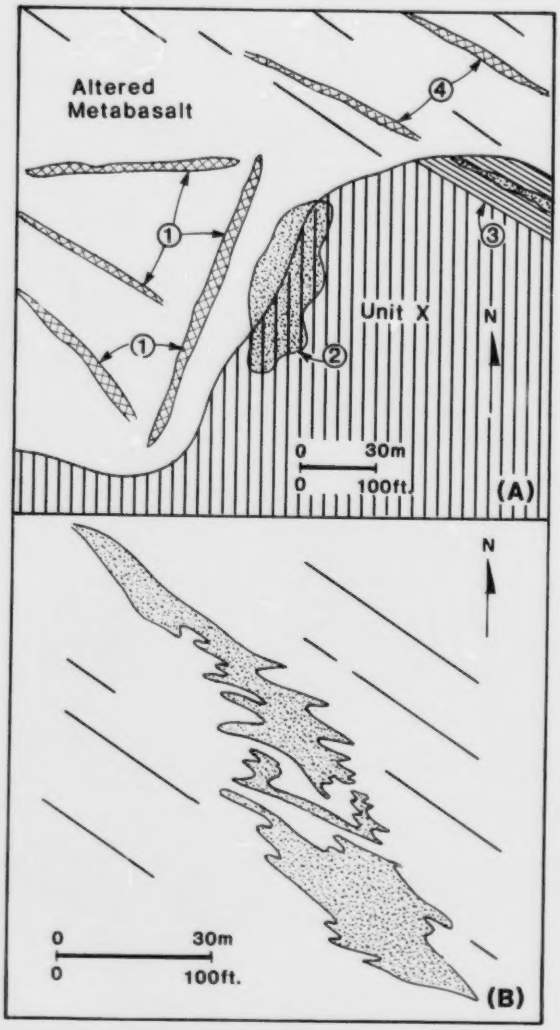

Figure 2. *(a) Schematic representation (in plan) of type (b) ore environments typical of the G and L zones, Campbell mine: (1) brecciated Fe-carbonate veins infilled and replaced by ore-bearing quartz and arsenopyrite (2) ore-bearing quartz-arsenopyrite replacement zones (3) ore-bearing arsenopyrite replacement band in sheeted veinlet zone (4) Fe-carbonate-quartz vein typical of ore environment type (a).*
(b) Plan view illustrating the general form of a disseminated sulphide replacement body (11-2955 stope) typical of environment type (b), A. W. White Mine (modified after 20 scale stope plan). In both figures, narrow oblique lines represent the trace of the foliation. (Project 40.)

this time constitute a major source of tonnage and grade.

STRUCTURE

Both mines are characterized by the pervasive presence of a strong northwest-southeast trending S-fabric (foliation) providing evidence of a penetrative ductile deformation event. Ductile features including stretched (prolate) pillows, mineral aggregates, mineral lineations, and stretch lineations indicate that the generation of the penetrative fabric was accompanied by a strong L (stretching) component. These features indicate a southwest plunging stretching direction which is consistent over the total volume of the mine workings. The stretching direction exhibits a rake varying from 60°SW to downdip on well developed foliation planes. The intensity of ductile deformation is quite variable as characterized by the sporadic occurrence of discrete, linear zones of very high strain uptake (mylonite zones). These zones are usually a few metres in width, strike persistent and trend northwest-southeast parallel to the main fabric.

The ductile deformation was both predated and postdated by periods of dominantly brittle to brittle-ductile deformation. Brittle deformation preceding ductile deformation is represented most obviously by the widespread occurrence of Fe-carbonate veins (not ore) and breccia zones. The breccia zones occur as highly irregular shaped bodies, usually a few metres in dimension and widely distributed throughout the amphibolite and greenschist domains of the mine complex within the mafic volcanic lithologies. They consist of closed to open frameworks of angular, mafic volcanic fragments within a matrix of Fe-carbonate. These breccia zones have been deformed during the subsequent ductile deformation such that they exhibit rotation into subparallism with the main S-fabric, folding, and sub-alignment of fragments. Similarly, Fe-carbonate veins exhibit folding, boudinage and rotation into subparallelism with the main S-fabric. The irregular form of the breccia zones combined with their wide distribution but rather non-systematic occurrence suggests that they may have originated due to hydraulic fracturing. Late brittle deformation postdating the ductile stage manifests as brittle, so-called 'black line' faults (mine term) which offset the ore zones, and less commonly, in the generation of pseudotachylite.

Throughout the mine complex, the response of Fe-carbonate veins to ductile deformation is characterized by two significant, related features best observed on crosscut walls and faces; (a) a distinct lack of symmetry in the distribution of both folded non-boudinaged (shortened) and boudinaged non-folded (stretched) veins relative to the trace of the penetrative S-fabric; and (b) a consistent asymmetrical relationship between veins showing both folding and boudinage and the penetrative S-fabric. These relationships indicate that the penetrative ductile fabric is due to a bulk, non-coaxial deformation (dominantly simple shear), which was superimposed upon the brittle to brittle-ductile features. If the deformation regime had been predominantly coaxial (e.g. flattening or pure shear), the result would have been a symmetrical disposition of veins about the S-fabric, which is not observed.

The observed asymmetry suggests a normal sense of shear, which is confirmed by the sense of rotation of synkinematic, metamorphic minerals observed in oriented thin sections from the A.W. White Mine (Hugon and Schwerdtner, in press). Since the main component of shear displacement occurred in the subvertical rather than the horizontal sense, deformed veins can be taken as significant kinematic indicators of the deformation regime *only as viewed on crosscut walls and not backs*, a situation apparently not recognized in the previous structural studies conducted in these mines (*see* Introduction). Moreover, when the Fe-carbonate veinlets can be observed along faces or raises, (i.e. along surfaces parallel to the principal plane of deformation containing the maximum shortening and stretching directions), they display geometrical relationships that are characteristic of Riedel shear fractures. The sense of shearing deduced from the geometry exhibited by these veinlets indicates a downthrow of the hanging wall relative to the footwall. The early brittle behaviour of the rock material in both mines is therefore due to the same normal faulting that subsequently created ductile features under conditions of decreasing viscosity. The decreasing viscosity is presumably due to progradation of the metamorphic front.

While orebodies are observed to crosscut the early brittle to brittle-ductile features, all orebodies within the mine complex have been affected by the ductile stage of deformation. Ore vein systems (type (a) environments in both mines) show evidence of both folding and boudinage, indicating that they have experienced both shortening and stretching components (either simultaneously or progressively) during continuous ductile deformation. The characteristic internal brecciation of the vein and replacement band structures reflect the mechanical behaviour of competent materials such as Fe-dolomite, arsenopyrite, and quartz during episodes of high strain rate (seismic release?) of the otherwise ductile deformation. Presumably the ductile behaviour corresponds to a steady, low strain-rate. The transition of this orebody type from bonafide, dilatent vein structures to dominantly replacement bands from northwest to southeast in the ore complex, is probably best ascribed to a transition from ductile-brittle to predominantly ductile conditions with increasing metamorphic grade in this direction.

The general shape and north-south configuration of the disseminated, sulphide replacement bodies in the A.W. White Mine (type (b) ore environments) are compatible with, and most logically explained in terms of, passive folding (a ductile response) during ductile deformation. The northwest-southeast S-fabric is generally axial planar to what are interpreted to be fold noses within these lensoid bodies (Figure 2b). Campbell type (b) ore environments (e.g. G and L zones) are controlled in local environments of dominantly brittle deformation preserved within the strain shadows of the rolling unit X contacts. As described above, immediately beyond these local domains the brittle features are observed to be deformed into the strong northwest-southeast ductile trend (Figure 2a).

On the basis of our preliminary observations, the early brittle, main ductile and late brittle deformations are viewed as progressive stages in a single continuous deformation event. This deformation characterizes a small but significant section of the Cochenour-Gullrock Lake deformation zone, which was generated during the emplacement of the Trout Lake batholith to the northeast. The ore structures were formed during, and as a result of, the ductile stage of deformation, but were themselves deformed during continuation of this ductile stage and the late brittle stages.

ACKNOWLEDGMENTS

We are most grateful to P. Busse (Manager, A.W. White Mine) and S.M. Reid (Manager, Campbell Red Lake Mine) for providing the surface and underground facilities and the long-term access necessary for this study. Of central importance to the successful completion of our field work was the professional and friendly cooperation extended to us by the geological staff of both mines. For their time, knowledge, and insight we extend our sincere appreciation to J. Rogers (Chief Geologist), M. Chowaniec, B. Gillies, and D. Lampman of the A.W. White Mine, and R. Church (Chief Geologist), B. Paryniuk, J. Misiura, and S. Bjarneson of the Campbell Red Lake Mine.

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S41. Structural Geology and Alteration Patterns Related to Gold Mineralization in the Confederation Lake Area

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INTRODUCTION

This two-year project was initiated to address the nature of and controls on gold mineralization in the Uchi-Confederation-Woman Lakes area (Location Map). The philosophy behind the project is distilled from the detailed observations made by many geologists over the years in the established gold mining camps of the Superior Province, that show the gold mineralization event occurred late in the lithotectonic evolution of a given greenstone belt (c.f. Colvine *et al.* 1984). This project provided an excellent opportunity to approach a greenstone belt at a reconnaissance scale to map strain intensity variations and alteration patterns, and to relate these and the lithological distribution patterns to sites of known gold mineralization. The area has been covered by recent 1:15 840 scale mapping (Thurston 1982) which provides an excellent lithostratigraphic geology base.

This approach differs from that normally undertaken by geologists of the Mineral Deposits Section, in that the geological perspective, at least for the first year, is reconnaissance in nature. In this regard, the following regional characteristics of this greenstone belt were addressed: (1) structural setting; (2) alteration patterns; (3) spatial and temporal relationships between these two features, rock type distribution and known sites of gold mineralization. Only one of the four major past-producing gold mines (Jackson-Manion) and several other showings having apparent gold potential were examined in detail.

Although the field work was carried out collaboratively, Lane focused primarily on the structural aspects and Fyon concentrated on the alteration and gold metallogenic features of the area. Fyon is also responsible for the structural and alteration description of the Woman and Uchi Lakes areas, which were examined after the departure of Lane from the Ontario Geological Survey.

This project was made possible through in-year supplementary funding by the Government of Ontario.

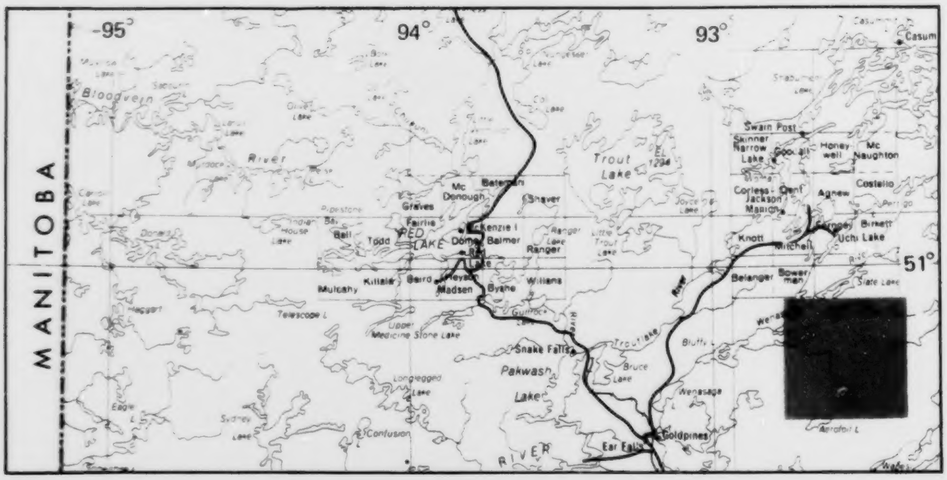
REGIONAL GEOLOGICAL SETTING

Three volcano-sedimentary cycles exist in the Confederation Lake area (Pryslak 1971a, 1971b; Thurston 1982). Each cycle begins with pillowed basalt and andesite flows and is capped by andesitic and rhyolitic pyroclastics and minor flows (Figure 1). Cycle 1 is interpreted to be a platform upon which Cycle 2 was deposited during the early stages of caldera development (Thurston 1982). Cycle 3, the product of resurgent volcanism, contains hypabyssal felsic intrusions and the South Bay Mine Zn-Cu-Ag massive sulphide deposit (Thurston 1982).

The lithological units generally strike north and have been folded into a north-trending syncline, the core of which is occupied by the Cycle 3 felsic volcanic rocks. The lithological package has been metamorphosed to greenschist and amphibolite grade and intruded by late felsic dikes and granitoid bodies. The Trout Lake Batholith is the largest such intrusive in the map area (Figure 1).

STRAIN STATE

In general, the strain state is characterized by a pronounced subvertical extension lineation. This is defined (in suitable rock types) by quartz-feldspar


-95°
94°
93°
51°
MANITOBA
Bloodvein
River
Olive Lake
Trout Lake
Swain Post
Skinner Narrow Lake
Goodall
Honey-well
Mc Naughton
Costello
Corless - Dent
Jackson Manion
Agnew
Birkett
Uchi Lake
Knott
Mitchell
Belanger
Bowerman
Slate Lake
Mc Donough
Bateman
Shaver
Graves
Fairlie
RED LAKE
Mckenzie I
Dome
Balmer
Ranger
Ranger Lake
Little Trout Lake
Joyce Lake
Indian House Lake
Ball
Todd
Killala
Baird
Heyson
Madsen
Byshe
Williams
Mulcahy
Telescope L
Upper Medicine Stone Lake
Snake Falls
Pakwash Lake
Troutlake
Bruce Lake
Bluffy L
Wenasaga
Longlegged Lake
Confusion
Eagle L
Sydney Lake
RIVER
Ear Falls
Goldpines
Casummit
Casum

LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

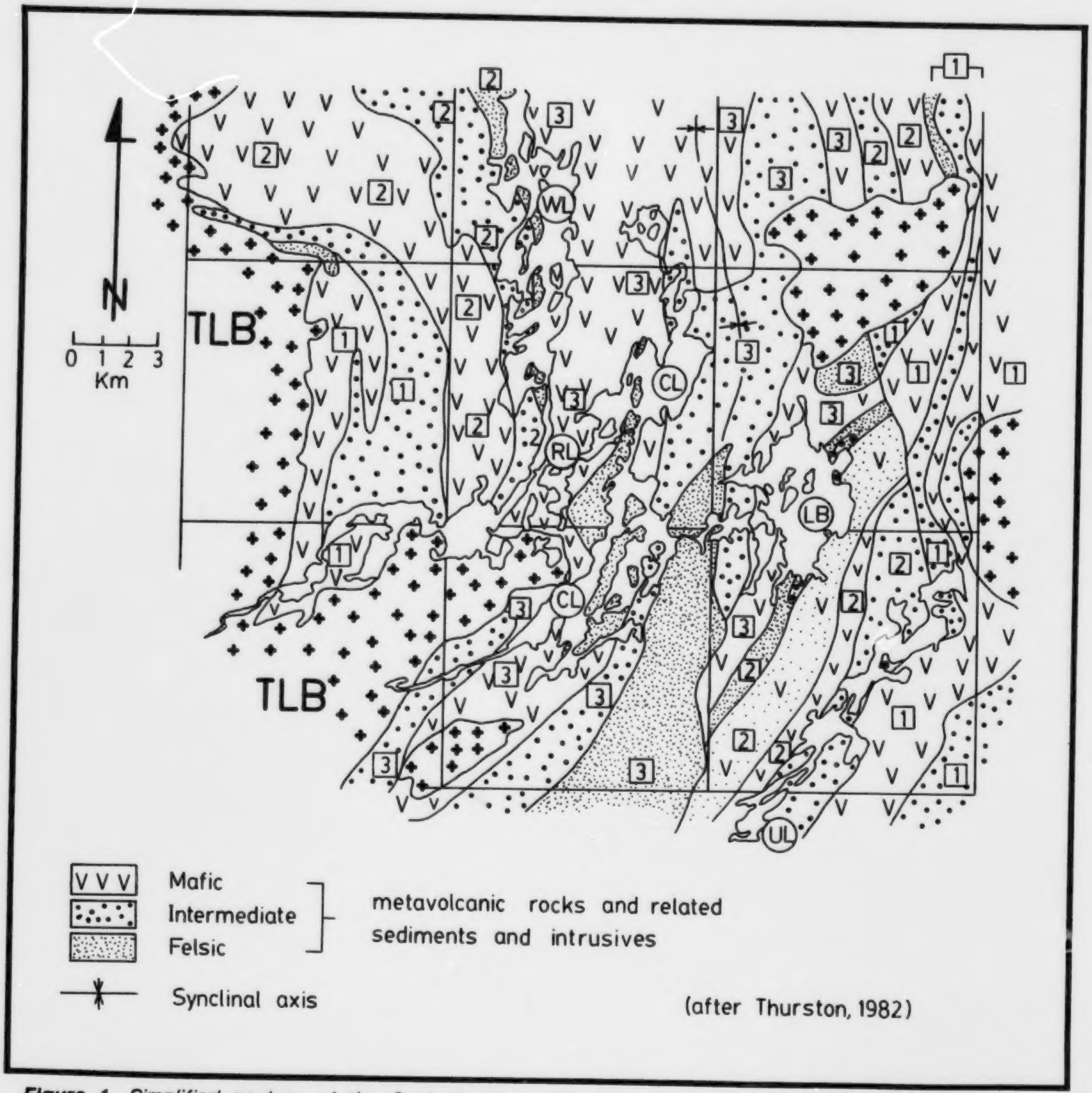

N
0 1 2 3
Km
TLB
TLB
WL
CL
RL
CL
LB
UL
1
2
3
Mafic
Intermediate
Felsic
metavolcanic rocks and related sediments and intrusives
Synclinal axis
(after Thurston, 1982)

Figure 1. *Simplified geology of the Confederation Lake area (after Thurston 1982). Abbreviations: WL, Woman Lake; RL, Rowe Lake; CL, Confederation Lake; LB, Lost Bay; UL, Uchi Lake; 1, 2, or 3 refer to the specific volcanic cycle, as defined by Thurston (1982, 1984); TLB, Trout Lake Batholith. (Project S41.)*

aggregate long axes; strain shadows adjacent to rigid inclusions (clasts, phenocrysts, porphyroblasts, etc.); and stretched clasts, amygdules, and varioles. Chlorite and white mica streaks, and long axes of actinolite grains define a lineation which is usually parallel to those defined above. Foliations are principally defined by chlorite and white mica, and locally biotite. They are parallel to the flattening plane defined by deformed inclusions, where present. Foliations strike north to northeast in the northern part of Confederation Lake, but are nearly east-west in the southern part of the map area (Figure 2). They are, in general, discordant with respect to the attitudes of the rock units. Reference will be made periodically to "highly strained" zones. This is a subjective assessment of the deformation intensity based on the development of a foliation and/or lineation in a given rock type.

DEFORMATION SEQUENCE

First Deformation (D1)

D1 has a variable, broadly north-striking foliation with a steep dip, and a subvertical extension direction. It

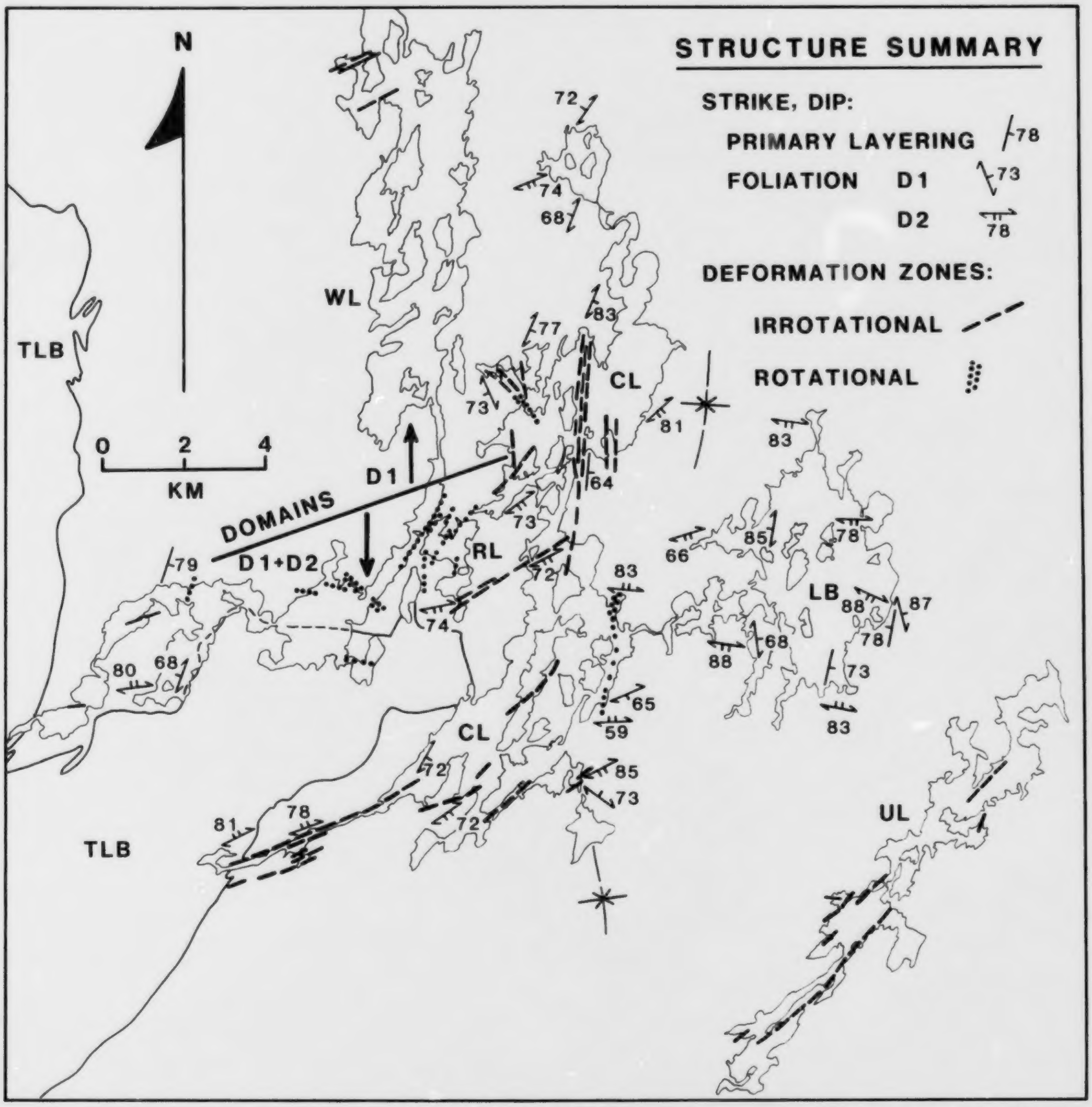

N
STRUCTURE SUMMARY
STRIKE, DIP:
PRIMARY LAYERING 78
FOLIATION D1 73
D2 78
DEFORMATION ZONES:
IRROTATIONAL
ROTATIONAL
0 2 4
KM
WL
TLB
CL
RL
LB
UL
TLB
DOMAINS
D1
D1+D2
72
74
68
83
77
73
81
83
64
73
85
78
66
72
83
88
87
74
79
78
68
88
73
80
68
65
59
83
CL
72
85
73
81
78
72
UL
TLB

Figure 2. Structural summary of the Uchi-Confederation-Woman Lakes area. Abbreviations: WL, Woman Lake; RL, Rowe Lake; CL, Confederation Lake; UL, Uchi Lake; TLB, Trout Lake Batholith. Pluton contact and syncline axial surface trace taken from Thurston (1984). (Project S41.)

is principally preserved in the northern part of Confederation Lake (Figure 2). The north strike of rock units and the synclinal axial surface trace defined by top indicators (Thurston 1984) are expressions of this deformation.

The isoclinal form indicates that the deformation intensity was high, on a regional scale. However, on a local scale, the deformation intensity, defined qualitatively by intensity of fabric development, varies from "not noticeably deformed" to "intensely deformed". Intensity and orientation of the foliation is partly controlled by rock type, e.g. metaplutonic and pillowed basalts show the weakest fabrics.

Minor folds, on scales up to a few metres, are locally observed to deform suitably oriented quartz veins. Metamorphic conditions of chlorite grade during the D1 event are indicated by syntectonic chlorite in the foliation.

Second Deformation (D2)

D2 predominates in the southern and eastern parts of the map area (Figure 2). D2 fabrics are not uniformly developed, and relict D1 fabrics coexist. Minor folds formed during D2 are locally observed to deform quartz veins and the earlier D1 fabric.

The D2 foliation strikes east-northeast, and has a moderate to steep dip, usually southward. The extension direction for D2 is generally masked by the pronounced vertical lineation produced by D1. However, at the southern end of Rowe Lake (R1, Figure 4), D2 fabrics and small-scale structures are well developed. Here, strain shadows adjacent to syn-D2 garnet porphyroblasts indicate that the extension axis for the D2 increment was shallow, east-west.

In the south Confederation Lake-Lost Bay area, rock units have retained their north-south strikes although foliations in those rocks strike nearly east-west. Therefore, the regional scale D2 strain intensity was low. A left-jog in a granodiorite unit axial to Confederation Lake may be a map-scale D2 S-fold. It is on strike with the well developed D2 structure at the southern end of Rowe Lake, where minor folds having S-sense predominate.

Third Deformation (D3)

Weak, small-scale crenulations are locally observed to overprint the D2 foliation, notably at the southern end of Rowe Lake.

DEFORMATION ZONES

Overview

Deformation zones are linear, with a well developed foliation and/or lineation, and therefore coincide with zones of high strain (as defined qualitatively above). Their genesis is varied: some were clearly formed in irrotational strain regimes associated with D1 or D2; others are clearly shear zones (rotational strain).

Five major deformation zones were defined: northern Confederation Lake, southern Confederation Lake, southern Rowe Lake, western Rowe Lake, and Uchi Lake. A number of smaller high-strain zones were identified, usually parallel and adjacent to the major zones (Figure 2).

Northern Confederation Lake

This north-striking zone is at least 500 m wide and 4 km long. It coincides with a succession containing variolitic flows, and lies at or near the east margin of a granodiorite pluton. At least two smaller parallel zones lie farther east. Foliations strike between 010° and 030° in the zone. They are defined by chlorite and by the flattening plane of deformed varioles. The down-dip extension axis is defined by long axes of varioles. Adjacent rocks outside these zones are weakly foliated or unfoliated. There is no mesoscopic evidence for rotational strain, except at a local scale, where the granodiorite/chlorite schist contact lies within the zone.

This zone is interpreted to relate to the development of the D1 isocline. Localized shearing and cataclasis at the granodiorite contact relates to differential motion on the west limb of the D1 syncline and reflects the contrast between the more competent granodiorite and less competent chloritic metavolcanic.

Southern Confederation Lake

Foliations in this zone (C1, Figure 4) strike northeast to east-northeast, and are defined by biotite and white mica in mafic to felsic metavolcanics. The extension lineation, defined by quartz-feldspar aggregates, strain shadows, and biotite streaks, pitches between 30° and 45° eastward in the foliations, but steepens towards the vertical near the point where the narrow reach of the lake broadens into South Bay.

Boudinaged quartz veins, oriented symmetrically at small angles both clockwise and counter clockwise from the foliation, indicate that the strain was irrotational. Involvement of biotite and garnet in the deformation indicates that it was syn- to post-metamorphic. This relationship to the metamorphism, the tendency towards a shallow extension axis, and the east-northeast foliation indicate that this zone (and probably adjacent parallel zones) developed as part of the D2 formation.

This zone projects into the Trout Lake Batholith. Foliation and lineation identical to those in the adjacent metavolcanics are restricted to the margin of the granite, indicating that it was involved in the (D2) deformation.

Southern Rowe Lake

This zone (R1, Figure 4) has already been described, in part, as it exemplifies the D2 formation. Progressing southward into this zone, the north-striking D1 chlorite foliation is increasingly crenulated and deformed into metre scale D2 folds outlined by quartz veins and small dikes. With increasing D2 strain, the early fabric is locally, then completely, replaced by a D2 chlorite fabric striking east-northeast. As previously noted, garnet porphyroblasts are involved in the deformation, and have strain shadows with shallow east-west orientations.

Western Rowe Lake

This area (R2, Figure 4) contains at least eight separate deformation zones varying from 1 m to more than 100 m wide. Most strike between 000° to 025°. Extension lineations plunge at shallow to moderate angles, usually <30°, towards both north and south. Pronounced chlorite foliations strike between 020° and 050°. A variety of asymmetric mesoscopic structures indicative of rotational strain consistently indicate a left-lateral shear couple. These structures include rotation of the foliation with increasing strain, carbonate and quartz-filled extension fractures, C and S fabrics, shear bands, and rotated minor folds.

Protoliths are predominantly mafic metavolcanics and metagabbro. In the zone comprising the Jackson-Manion gold property, a metagabbro, a quartz-feldspar porphyry dike, and at least two generations of quartz and quartz-tourmaline veins were involved in the shearing. A third set of smaller quartz veins oriented as extension fractures in the shear couple appears to have been emplaced late in the deformation.

The major deformation zone occupying the isthmus between Rowe and Woman Lakes contains both

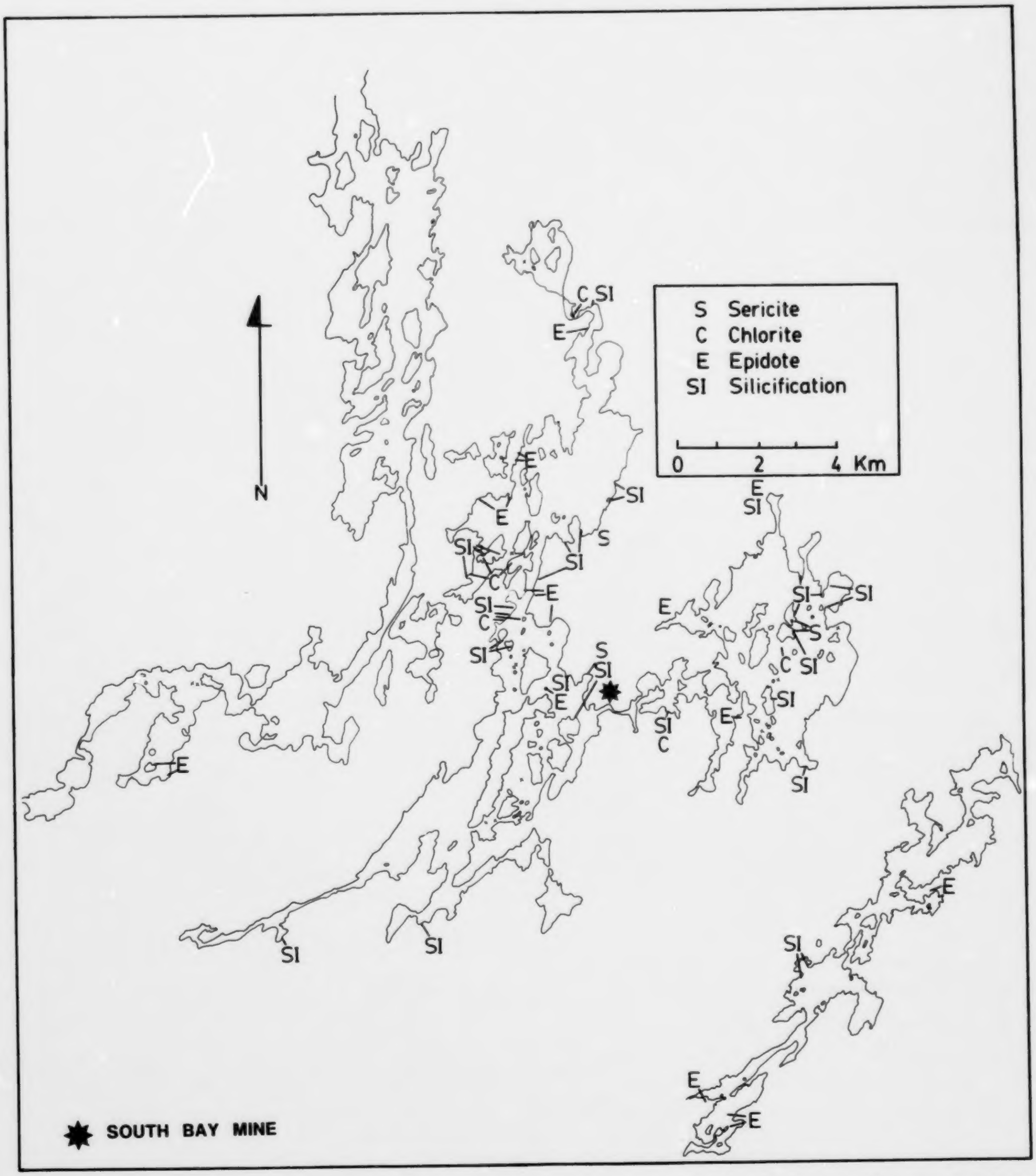

S Sericite
C Chlorite
E Epidote
SI Silicification
0
2
4 Km
N
SOUTH BAY MINE
C SI
E
E
SI
E
SI
E
SI
S
SI
C
SI
E
SI
C
SI
S
SI
SI
E
SI
C
E
SI
SI
S
C SI
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Figure 3. Geographical distribution of early (pre-D1) alteration types in the Confederation Lake area. (Project S41.)

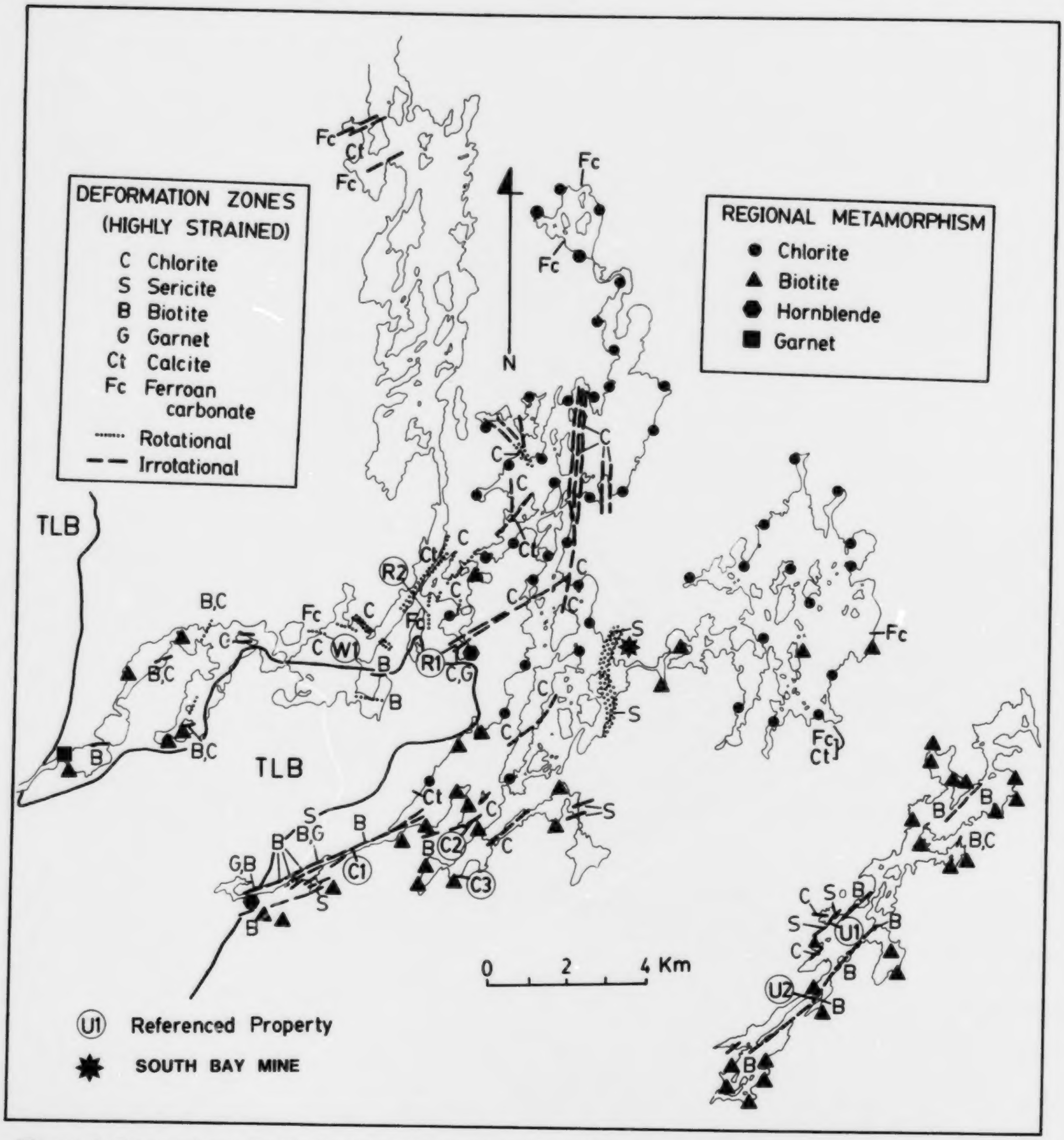
DEFORMATION ZONES (HIGHLY STRAINED)
C Chlorite
S Sericite
B Biotite
G Garnet
Ct Calcite
Fc Ferroan carbonate
Rotational
Irrotational
REGIONAL METAMORPHISM
Chlorite
Biotite
Hornblende
Garnet
N
TLB
0 2 4 Km
U1 Referenced Property
SOUTH BAY MINE
R1
R2
W1
C1
C2
C3
U1
U2

Figure 4. Geographical distribution of metamorphic index minerals, syndeformation alteration minerals in the highly strained zones, and the locations of properties referenced in the text. (Project S41.)

mafic and intermediate volcanic rocks as well as quartz-feldspar porphyry dikes.

Timing of shear displacements is presently unconstrained. However, left-lateral displacements on zones of these orientations are consistent with a dynamic state which could also give rise to the low-strain D2 deformation (i.e. instantaneous flattening plane oriented east-northeast/vertical, with a shallow extension axis).

Uchi Lake

A highly strained zone runs northeast axial to Uchi Lake. This zone is about 100 m wide and has been interpreted as a fault splay off the Sydney Lake cataclastic zone (Thurston and Breaks 1978). However, extension lineations are all steep, unlike the roughly horizontal extension lineations associated with the Sydney Lake cataclastic zone (Breaks *et al.* 1978). Chlorite and biotite foliations strike between 030° and 050° and dip steeply.

Several northeast-trending fold axes occur in and to the east of the Uchi Lake area. One such south-plunging anticline, whose axial plane corresponds with the surface trace of the highly strained zone, is exposed in the Neepawa Bay area of Uchi Lake. These preliminary observations suggest that the steeply plunging extension lineations within the Uchi Lake highly strained zone did not develop during the same rotational deformation event which imposed the subhorizontal lineations in the Sydney Lake cataclastic zone. Rather, the Uchi Lake deformation zone is interpreted to have developed during an irrotational D1 deformation event.

STRUCTURAL SUMMARY

The map area has undergone a multiphase deformation history beginning with an initial intense deformation (D1) resulting in regional scale isoclinal structures striking north with a subvertical extension direction. On a local scale, penetrative strain varies from very low to intense, with a locally well developed chlorite foliation. North-striking deformation zones are interpreted as zones of accommodation at contacts between units of different competence. Linear granodiorite and metagabbro bodies were involved in this deformation.

The second deformation (D2), affecting the southern part of the map area, produced locally well developed chlorite and biotite foliations striking generally east-northeast. Where extension directions relating to D2 can be distinguished from the intense D1 lineation, the L2 directions are east-west with shallow plunges. Locally developed garnets were involved in at least some of the D2 deformation. East-northeast-striking deformation zones on Confederation and Rowe Lakes, characterized by irrotational strain, relate to D2. Although no evidence of direct correlation was observed, the shear zones exposed on Rowe Lake are also consistent with a development during D2. Fabrics concordant with D2 occur at the margin of the Trout Lake Batholith, indicating that it was present during that deformation.

REGIONAL ALTERATION PATTERNS

Although it is recognized that the alteration history of the area represents a broad continuum, a simplistic subdivision has been made to distinguish very early (pre-D1 deformation) alteration from alteration related temporally to subsequent regional deformation and metamorphic events.

EARLY ALTERATION

Epidotization, silicification, sericitization, and chloritization, listed from oldest to youngest, are the pre-D1 alteration types (Figure 3). The epidote alteration is manifest either as spherical or elliptical (where deformed) domains up to 40 cm in diameter or as veinlets. The more advanced stage of this alteration, where observed in pillowed basaltic flows, produces a bleached, light green coloured rock. This alteration affects most rock types in the area, but seems to be more widespread in the mafic and intermediate rocks of Cycle 3 within 1 km of the former South Bay Mine, a volcanic-hosted Zn-Cu-Ag deposit. Silicification of extrusive volcanic rocks of Cycle 3 also is commonly observed in proximity to the South Bay Mine. This alteration initiates along fractures, producing in the more intensive stages a rock which is cherty in appearance. Sericitization also initiates along fractures and ultimately yields a product which is strongly sericitic. Chlorite is present as an accessory phase in most rocks in the area. However, more intense chloritization occurs in a spotty habit or is manifest as a more pervasive replacement mineral associated with Cycle 3 extrusive flows and felsic dikes on Confederation Lake to the west of the South Bay Mine. Chlorite also occurs as an alteration halo about fractures and quartz veins cutting the granodiorite body which trends north through Confederation Lake.

SYNDEFORMATIONAL ALTERATION

Figure 4 illustrates the distribution of chlorite, biotite, and garnet in relatively low strained rocks. The distribution of these minerals reflects the regional metamorphic grade in the belt. The distribution of biotite suggests its stability is controlled either by an east-west trending thermal isograd parallel to the English River Gneiss Belt, or by the granitoid bodies which define the east and west boundaries of the belt. The distribution of garnet appears to be more closely tied to the Trout Lake Batholith. Chlorite, without co-existing biotite or garnet, is stable to the north of the biotite isograd.

Figure 4 also illustrates the distribution and mineralogy of the highly strained (deformation) zones. In general, the mineralogy within the highly strained zones is identical to that in the adjacent low strained rocks.

GOLD MINERALIZATION

Zones of interest examined in 1985 are discussed on a geographical basis by lake. Locations are shown on Figure 4.

UCHI LAKE

Pyrite occurs in a northeast-trending siliceous, sericitic schistose zone (U1, Figure 4) as: (1) disseminated grains in the sericitic, schistose domains devoid of quartz veining; (2) veinlets in silicified zones; and (3) disseminated grains which envelope deformed quartz veins. At the outer edge of this zone where lozenges of low-strain rocks persist, pyrite is restricted to anastomosing, highly strained and sericitic zones, indicating that the pyritization and sericitization were initiated during the deformation event. This zone averages 3 m in width along the 0.5 km of its exposure. The protolith is not clearly identifiable because of the strong deformation and local intense silicification. This zone is controlled by Orofino Resources Limited.

A second pyritic zone (U2, Figure 4) is hosted by a northeast trending highly strained zone in bleached, sericitic, intermediate pyroclastic breccia. Pyrite abundance averages 5% across 2 m width. This zone has only been exposed recently and does not appear to have been prospected.

CONFEDERATION LAKE

Three pyritic zones occur in the southern half of the lake. The most continuous one (C1, Figure 4) has been traced for 3.5 km and is hosted by highly strained, siliceous and sericitic felsic pyroclastics. Garnet and biotite occur as accessory minerals. Pyrite is generally low in abundance but occurs erratically as disseminated grains and veinlets along the entire length of the southwest arm.

A second pyritic zone (C2, Figure 4), carrying accessory pyrrhotite and rare chalcopyrite, crops out continuously along a strike length of 0.5 km and trends northeast. The host rock is highly strained and chloritic and appears to be a basaltic flow from Cycle 3.

Up to 10% disseminated fine grained (<2 mm) pyrite occurs in a silicified zone which crops out on the southeastern shore near the access road to the South Bay Mine (C3, Figure 4). This zone, exposed over 5 m, bears no well developed foliation. Too little exposure is available to determine the strike of the zone.

ROWE LAKE

Two zones of interest, including the former Jackson-Manion Mine, are exposed on Rowe Lake. Both zones are controlled by Orofino Resources Limited. A strongly chloritized, sulphidic schistose zone (R1, Figure 4), hosting discontinuous and deformed quartz veins, is developed in vesicular basaltic flows. Garnet is preferentially developed in the chloritic wallrock adjacent to the quartz vein arrays. Pyrite and pyrrhotite occur as: (1) a vesicle filling with quartz; (2) veinlets which parallel or crosscut the foliation; and (3) sulphidization envelopes about deformed quartz veins. Most of the sulphide mineralization occurs in habits (2) and (3). At the outer margin of the zone, where low strained, weakly chloritized lozenges of basalt occur, veinlet and disseminated sulphide mineralization is restricted to the anastomosing, strongly foliated and chloritized rock. Quartz veins, boudinaged and necked during the D1 folding event, also carry sulphidization haloes. These observations indicate that sulphide introduction began pre- or syn-D1 as vesicle fillings and quartz vein sulphidization envelopes, and continued during the D2 deformation event as sulphide veinlets contemporaneous with the chlorite alteration. This highly strained zone trends northeast and is exposed on Confederation Lake, where no sulphide mineralization is present.

In the former Jackson-Manion Mine (R2, Figure 4), gold was won from north-trending, steeply dipping, quartz-tourmaline veins localized within a sinistral transcurrent shear zone. The sheared host rocks are a gabbro intrusion and basalts which have been cut by quartz-feldspar porphyry dikes. Pyrite is the most common sulphide, accompanied by traces of sphalerite and chalcopyrite. Most of the auriferous pyrite occurs in tourmaline-cemented breccia zones in vein quartz or wallrock. Rusty weathering ferroan carbonate alteration is locally present in the shear zone, although the sheared gabbro is primarily chloritized. The following tentative chronological sequence describes the evolution of the zone: (1) intrusion of the gabbro; (2) intrusion of quartz-feldspar porphyry dikes; (3) brittle failure of the gabbro and felsic intrusions and introduction of a milky-white, quartz vein accompanied by sparse, coarse pyrite; (4) brecciation of the early milky-white quartz vein, the gabbro and felsic intrusions accompanied by the introduction of tourmaline, which cemented the brecciated material, and the introduction of fine grained pyrite and gold; (5) ductile shearing, during which the gabbro, felsic dikes, and the tourmaline-cemented breccia were deformed; (6) introduction of a second banded quartz-tourmaline crack/seal vein; (7) late brittle failure accompanied by the development of quartz-filled tension fractures, which cut the earlier quartz veins, the tourmaline-filled breccia zones, and the sheared gabbro wallrock. The paragenetic position of the ferroan carbonate is less well constrained, although it is certain that the ferroan carbonate crystals are cut by tourmaline veinlets.

Ferroan carbonate occurs only at the Jackson-Manion Mine. In all other shear zones found on Rowe Lake, calcite is the stable carbonate mineral.

WOMAN LAKE AREA

Only the southern part and a small part of northern Woman Lake were examined this season. In the southern area, a number of east-west trending, narrow (<5 m) deformation zones are localized in, or more commonly along, the contacts of gabbro or pyroxenite dikes. Quartz veins, generally deformed, commonly are localized in these highly strained zones and carry chlorite, biotite, chalcopyrite, pyrrhotite, and pyrite. The quartz vein zones vary in width from 1 to 5 m. The mafic dikes are chloritized adjacent to the vein zone. Few of these vein systems appear to carry economic gold concentrations. Given the possibility that the metals have been redistributed from the adjacent mafic dikes, these zones may carry concentrations of some platinum group elements. Several east-west trending shear zones are developed along the north shore of Little Woman Lake to the west of Rowe Lake. Calcite is present in all these zones, but is locally accompanied by ferroan carbonate. One of the more interesting zones is exposed on the Frank property (W1, Figure 4), where deformed, milky-white quartz-iron carbonate veins up to 1 m in width are localized in a shear zone. A thin (<1 m) grey quartz feldspar porphyry dike trends along the south boundary of this zone. The sheared basaltic wallrock is locally replaced by ferroan carbonate, fine grained (<2 mm) pyrite, and sericite. This zone trends approximately 110° and dips south at 45° to 60°. It has been traced on surface for at least 400 m.

In the small area of the northern part of Woman lake that was examined (Figure 4), highly strained zones trending 060° are characterized by intense foliation and abundant ferroan carbonate veining. These veins range up to 1 m in width. Quartz veins are also present, but are not prominent in the areas examined. Little sulphide mineralization was observed in this zone.

TYPE OF DEFORMATION REGIME AND GOLD MINERALIZATION POTENTIAL

The highly strained zones identified during this study have been grouped into irrotational and rotational deformation regimes. A preliminary assessment of the gold-bearing potential of these two deformational regimes is cautiously offered, based on the nature and frequency of the mineralized zones observed. The character of some deformation zones is uncertain pending microscopic examination.

The major deformation zones exposed on Confederation and Uchi Lakes and the R1 zone on Rowe Lake appear to be of the irrotational type. A number of interesting zones occur in these highly strained zones, although none of these zones have yet been host to economic concentrations of gold. The Jackson-Manion Mine lies within a transcurrent shear zone which is part of a 2 km wide rotational deformation zone dominated by such structures. Several deformation zones located in the Bear-Woman Lakes area which trend east-west, and include the Frank showing, also have a dominant rotational component; however, insufficient information is available from the Woman Lake system to assess its precious metal potential. Thus, on the basis of the present limited database, it appears that only those deformation zones which had a major rotational component are host to economic concentrations of gold.

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42. The Geological Setting of the Duport Gold Mine, Shoal Lake, District of Kenora

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INTRODUCTION

A detailed study of the Duport Mine was initiated in 1984 (Smith 1984) as part of a regional study of gold mineralization in the Lake of the Woods area (Davies 1983; Davies and Smith 1984), in order to fully document the geological setting of the largest gold deposit in the area. The detailed study should establish a better understanding of geological controls affecting gold mineralization in the region, thus enabling the formulation of better exploration guidelines.

Work in 1984 focused on the immediate area of the Duport Mine. This work (Smith 1984), which included underground mapping and logging of diamond drill core, resulted in the recognition that the Duport orebodies are hosted by an anomalously deformed package of rocks, the Duport Deformation Zone (DDZ) (Smith 1984), within a steeply west-dipping sequence of mafic and ultramafic rocks.

Work in the 1985 field season was intended to complete the documentation of the geological setting of the Duport Mine, and to establish the regional context of the deposit. An area approximately 20 km^2 was mapped at a scale of 1 inch to 330 feet, and critical parts of the surrounding area were mapped at a scale of 1 inch to 1/2 mile. Fifty-three diamond drill holes were logged to provide six sections through the deposit, and six samples were taken for U-Pb zircon dating.

GENERAL GEOLOGY

Previous geological mapping, by Bell (1882), Greer (1931), and most recently by Davies (1978), is summarized in Smith (1984).

Regional stratigraphic studies, with special emphasis on chemical composition of volcanic units, were completed by Goodwin (1965, 1970).

The volcanic rocks in the Shoal Lake area have been subdivided into an older (lower) komatiitic-tholeiitic series (LKTS) and a younger (upper) calc-alkalic series (UCS) (Davies and Smith 1984; Smith 1984) (Figure 1). Mafic volcanic rocks, exposed in the northwestern part of the map area (Figure 1), appear to overlie the UCS and may represent a second, younger mafic cycle. The volcanic succession has been folded about a northeast-trending anticline, referred to by Davies (1978) as the Gull Bay-Bag Bay anticline (Figure 1). Several felsic bodies intrude the volcanic package; some have been observed only within the LKTS as sills, and others intrude both the LKTS and UCS as dikes, stocks, and batholiths.

LOWER KOMATIITIC-THOLEIITIC SERIES

The northeast-trending stratigraphic succession of the LKTS is best exposed west of the Gull Bay-Bag Bay anticlinal axis in the east central part of Figure 1. Feldspar-phyric basalts are the oldest exposed rocks of the LKTS. These form a striking marker horizon, characterized by subhedral to euhedral feldspar phenocrysts up to 5 cm in size. The phenocrysts vary in abundance from >30% to <1%. Commonly the unit is pillowed, but there are massive, medium grained equivalents along strike. Overlying this unit are massive and pillowed aphyric basalts which have been intruded, and in part displaced, by a medium-grained gabbro sill.

Ultramafic and basaltic komatiitic flows and sills overlie the aphyric basalt, and form a series of distinctive mappable marker units. The ultramafic rocks include peridotite, pyroxenite, and nematoblastic amphibolite. The basalt is pillowed, variolitic, and is capped by massive basalt locally displaying spinifex textures. A gabbro sill also intrudes this part of the LKTS.

A second, non-pillowed, porphyritic marker unit overlies the komatiitic series. This unit is also characterized by abundant feldspar phenocrysts, but is consistently massive and medium grained, grading northwestward into a massive finer grained equivalent. It is not clear whether this unit is a coarse flow or a sill. Massive and pillowed aphyric basalts overlie the porphyritic unit to the northwest.

UPPER CALC-ALKALIC SERIES

The UCS occupies much of the western part of the map area (Figure 1). The series is characterized by dacite tuffs and tuff breccias, intercalated with andesitic tuffs and flows, basaltic tuffs and flows, reworked tuffaceous sediments and chemical sediments.

Units trend northeast to east-northeast. Stratigraphic tops, determined within the sediments and pillowed basalts, are consistent with the northwest-facing homoclinal succession observed within the LKTS.

INTRUSIVE ROCKS

A major diorite/quartz diorite intrusion, the Stevens Island Complex (Davies 1978), intrudes the LKTS in the north central part of the study area (Figure 1). This northeast-trending intrusion extends past the northern boundary of the study area; the southern margin is gently curved, trends roughly east, and intrudes northwest-facing feldspar-phyric and aphyric basalt flows intercalated with minor ultramafic flows. The southeastern part of the complex is diorite in composition, with patches of remnant primary hornblende and local xenoliths of the host volcanic rocks. In places, small stringers and dikes of the diorite intrude the host basalts. A moderately well developed mafic-felsic layering is found locally, particularly proximal to the southeast contact. To the west, the diorite is in contact with an anorthositic phase, succeeded farther west by quartz diorite, and locally alaskite. This differentiation towards the northwest is consistent with facing directions observed within the host volcanic flows, suggesting that the intrusion may

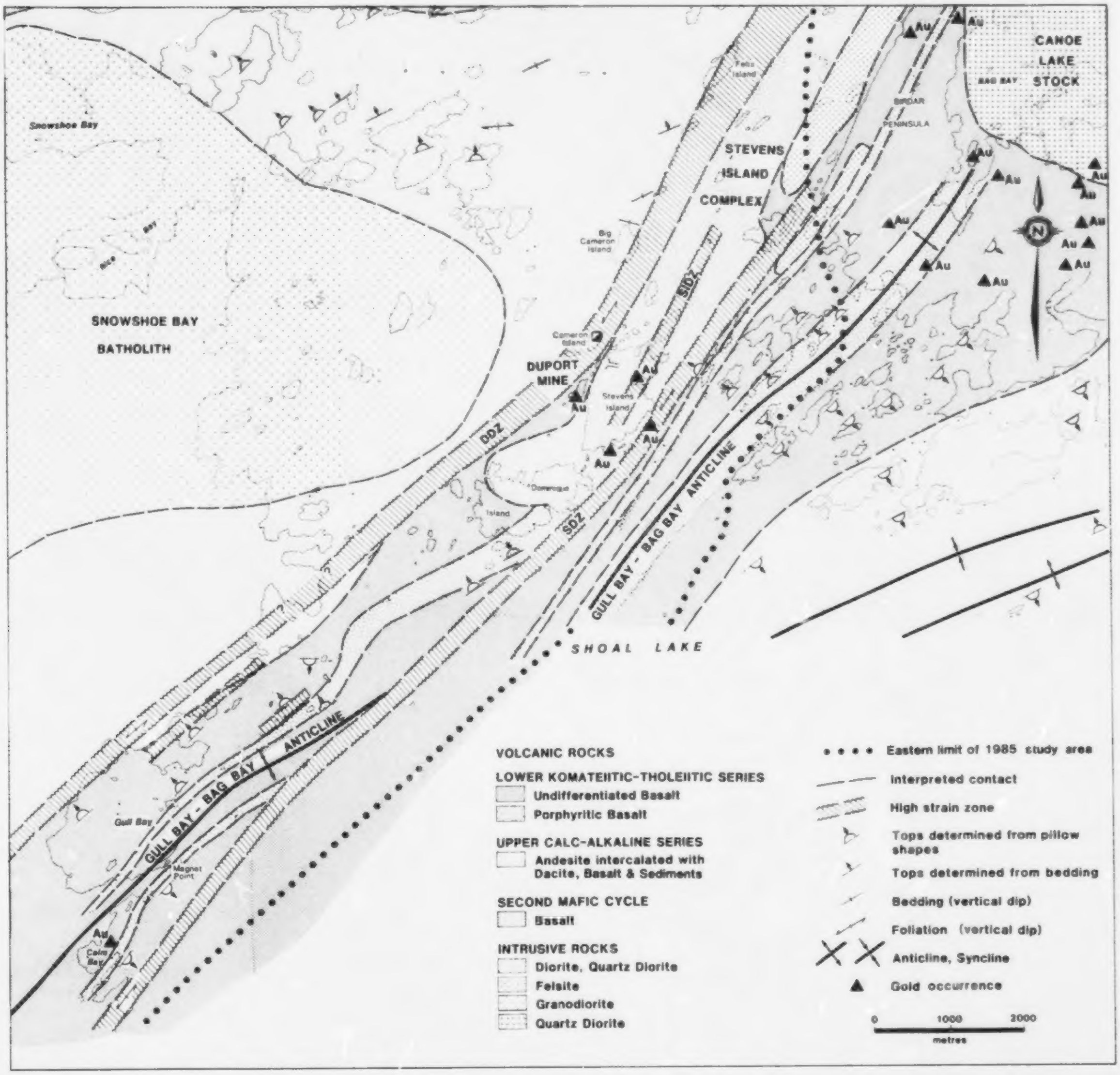
CANOE
LAKE
STOCK
BAG BAY
SIRDAR
PENINSULA
Snowshoe Bay
Rice Bay
STEVENS
ISLAND
COMPLEX
Big
Cameron
Island
Cameron
Island
SNOWSHOE BAY
BATHOLITH
DUPORT
MINE
Stevens
Island
Dominique
Island
SIDZ
DDZ
GULL BAY - BAG BAY ANTICLINE
SHOAL LAKE
Gull Bay
Magnet
Point
Calm
Bay
Au
N
VOLCANIC ROCKS
LOWER KOMATEIITIC-THOLEIITIC SERIES
Undifferentiated Basalt
Porphyritic Basalt
UPPER CALC-ALKALINE SERIES
Andesite intercalated with Dacite, Basalt & Sediments
SECOND MAFIC CYCLE
Basalt
INTRUSIVE ROCKS
Diorite, Quartz Diorite
Felsite
Granodiorite
Quartz Diorite
Eastern limit of 1985 study area
Interpreted contact
High strain zone
Tops determined from pillow shapes
Tops determined from bedding
Bedding (vertical dip)
Foliation (vertical dip)
Anticline, Syncline
Gold occurrence
0
1000
2000
metres

***Figure 1.** Generalized geology of the Shoal Lake area (modified from Davies 1978). (Project 42.)*

be a sill emplaced prior to tilting on the volcanic stratigraphy.

A small, elongated fine grained felsic body intrudes the LKTS along the western shore of the Sirdar Peninsula (Figure 1). This intrusion appears stratabound and may be a sill related to the UCS.

Two large felsic bodies intrude the volcanic succession within the area (Figure 1). The Snowshoe Bay granodiorite batholith intrudes the UCS about 1 km west of the Duport deposit, and extends west into Manitoba. The Canoe Lake quartz diorite stock intrudes the LKTS roughly 6 km northeast of the Duport deposit. It appears to truncate the Gull Bay-Bag Bay anticline (Figure 1) and cuts through the UCS on the southeast limb of that fold. A tentative U-Pb radiometric age of the Canoe Lake Stock is 2.708 b.y. (D. Davis, Geochronologist, Department of Geology, University of Toronto, Toronto, personal communication, 1985).

Numerous felsic dikes are found throughout the map area, displaying a variety of crosscutting relationships.

Late lamprophyre dikes have been observed to crosscut all lithologies, with the possible exception of the Canoe Lake stock and Snowshoe Bay batholith, within which no lamprophyre dikes were recognized.

METAMORPHISM

Regional metamorphism is lower greenschist facies. An amphibolite grade aureole surrounds the Snowshoe Bay batholith; however, its maximum extent has not been delineated at present.

STRUCTURE

The LKTS-UCS Boundary

Due to the proximity of the Duport deposit to the northeast-trending contact between the UCS and the LKTS (Figure 1), special emphasis was placed on ascertaining the nature of that contact during the study. Detailed mapping of the contact area indicated that stratigraphic units, within both the UCS and the LKTS, are traceable at an oblique angle into the boundary area, where the units are truncated. In the northwestern part of the study area, within the UCS, the dominant foliation trends roughly east. This east-trending foliation was not recognized within the contact area, where the rocks are very strongly foliated parallel to subparallel to the contact. The intensity of this foliation, particularly within the volcanic rocks in the northern part of the study area and within the immediate mine workings, increases towards the boundary. The contact is covered by water, but on islands close to the boundary area, individual fragmental units are traceable into mylonites and ultramylonites. Fabric development within the host volcanic rocks is oblique to bedding at similar angles to those observed between the traceable units and the contact zone. In addition to the foliation development, both volcanic rocks and volcanogenic sediments are folded and faulted within the boundary zone. Felsic dikes within the zone are mylonitized, and even the late lamprophyre dikes are offset and folded. Boudinage and boudinage-like features are also common. Quartz carbonate-filled tension gashes are ubiquitous and in general trend slightly west of north. A second set of quartz and quartz carbonate veins trend parallel to subparallel to the foliation. On the whole, the deformed rocks within the boundary zone contain considerably more carbonate and quartz than undeformed, unaltered equivalents; tourmaline veins are also abundant locally, particularly within more felsic rocks.

The combination of alteration, deformation, and in particular the truncation of lithologic units within the contact area, identifies the contact as a fault contact, rather than a disconformity or unconformity. If it were either of the latter two, truncation of units would only be possible within the underlying series; whereas, in this case truncation occurs on both sides of the contact. The steep mineral lineations, extensional features, and fabric development observed throughout the deformed zone are consistent with the reverse, near-vertical movement documented within the Duport Deformation Zone (DDZ) (Smith 1984). In the northern part of the study area, the LKTS-UCS boundary is, then, the lateral extension of the DDZ, since it not only displays the same strain indicators but lies along strike and encompasses the DDZ. More work must be done in the southern part of the study area before any contact relationships there may be firmly established.

High Strain Zones

In addition to the Duport Deformation Zone (DDZ), there are at least two additional northeast-trending, linear, parallel to subparallel zones of high strain, the Sirdar Deformation Zone (SDZ) and the Stevens Island Deformation Zone (SIDZ).

The SDZ is located east of Stevens and Dominique Islands, and has been traced as far south as Magnet Pt. and as far north as the Sirdar Peninsula (Figure 1). Much of the core of this deformed zone is underwater and, as a result, examination of it was concentrated along the margins. Like the DDZ, relatively undeformed volcanic and intrusive rocks, including the Stevens Island Complex, pass through increasing degrees of deformation towards the SDZ, although the strain varies according to the rock competency. Foliation is parallel to subparallel to the zone margins. Boudinage and other extensional features are consistent with those within the DDZ (Smith 1984). Felsic and lamprophyre dikes within the SDZ are folded and offset, similar to those observed within the DDZ (Smith 1984). Crosscutting vertical faces display "S" fabric (schistosity) rotated into a west-dipping "C" fabric (shear planes), consistent with the reverse movement observed underground in the Duport Mine (Smith 1984). Mineral lineations recorded within the SDZ indicate near vertical movement.

Like the DDZ, the SDZ appears to be a reverse fault zone. In addition to the sense of movement recorded within the actual fault zone, the stratigraphy west of the SDZ is similar to that to the east. In the southern part of the study area, west of the SDZ, there is clearly a facing reversal (Figure 1), and feldspar-phyric basalt again occurs in the core. This is possibly an up-faulted equivalent of the Gull Bay-Bag Bay anticlinal axis establishing the area between the DDZ and SDZ as a repetition of the sequence lying east of the SDZ. Alternatively, it may represent a second western anticline (with no indication of the intervening syncline), a displacement of the Gull Bay-Bag Bay anticline by an unrecognized easterly fault system, or a repetition of a similar sequence overlying that east of the SDZ.

The SIDZ, like the DDZ and SDZ, is characterised by strong fabric development. Although much of the SIDZ lies within the Stevens Island Intrusion (Figure 1), several discontinuous zones of high strain are distinguishable within the volcanic rocks along strike to the southwest which may be related to the SIDZ. Foliation is parallel to subparallel to the zone margins, but varies in intensity. Grain size reduction (mylonitization) is readily apparent on the macroscopic scale in numerous locations. Within the zone, both felsic and lamprophyre dikes are offset and truncated. No small scale structures, which can be used to establish a sense of movement, were recognized along the SIDZ. However, there are near-vertical lineations and extensional features, consistent with the SDZ and DDZ.

The similarities along the three aforementioned deformation zones are quite striking. In addition, the proximity of the three zones suggests that they are related to the same west-side-up faulting event, and that each is a component of a larger whole.

DISTRIBUTION OF GOLD MINERALIZATION

Gold mineralization close to and within the study area is found within virtually all lithologies, with the possible exception of the lamprophyre dikes and the Snowshoe Bay batholith. All of the known occurrences, except one, are located within about 3 km of a major intrusion. Only three known occurrences in the area are hosted by the UCS. These are rather small and are located north and east of the study area. There are a number of occurrences located within structures inside the margin of the Canoe Lake Stock, northeast of the study area. At least one of these, the Mikado Mine, extends into the host mafic volcanic rocks. The bulk of the occurrences, like the Duport Mine, are located within the LKTS, both within the Stevens Island Intrusion and in mafic volcanic rocks.

In the study area, there are seven gold occurrences and one past producer, the Duport Mine (Figure 1). All of these occur within the LKTS, although four are hosted by the Stevens Island intrusion. All of the occurrences are found within, or very close to deformation zones.

STYLE OF GOLD MINERALIZATION IN THE STUDY AREA

The known deposits have two distinct styles of mineralization: (1) well bounded quartz veins containing more or less sulphide mineralization and, in places, free gold; (2) replacement bodies, characterized by strong fabric development, quartz network veining, silicification, and considerable sulphide mineralization.

THE DUPORT DEPOSIT

There are two main zones of gold mineralization in the Duport deposit, the East Zone (EZ) and the Main Zone (MZ) (Smith 1984). Several additional mineralized zones have been intersected through diamond drilling, but insufficient work has been done on them to date to ascertain their significance. Examination of drill core within the immediate mine area was consistent with findings of the 1984 underground work (Smith 1984). The MZ trends parallel to the DDZ and dips steeply west, while the EZ trends slightly more easterly and has a somewhat more shallow dip. The two ore zones appear to converge to the south and at depth. Both the MZ and EZ transect a variety of lithologies, including volcanic marker units and felsic dikes, clearly establishing the zones as fault controlled (Smith 1984). In addition, three mafic and ultramafic marker horizons were traced at an oblique angle into the MZ where they clearly are truncated. One late felsic dike set has been observed to transect the ore zones. Both the felsic dike types, those which crosscut the ore, and those crosscut by the ore, have been sampled for U-Pb dating. This should establish a maximum and minimum age of mineralization.

Cursory petrographic examinations of a selection of samples taken across the DDZ indicate an amphibolite grade mineralogy overprinted by a later greenschist grade mineral assemblage. The former occurs outside the DDZ, in the marginal areas of the zone, and within lithons (less deformed volumes of rock) within the DDZ, while the greenschist grade mineral assemblage dominates the core area.

DISCUSSION

Based on crosscutting, intrusive, and overprinting relationships, the following sequence of temporal relationships (Figure 2) has been constructed.

Gold occurs within virtually all lithologies in the area, although it is concentrated within rocks of the LKTS. Gold-bearing zones occur within, or in rocks affected by, regional linear structures which crosscut all lithologies, excepting possibly the Snowshoe Bay Bay batholith and lamprophyre dikes. These structures may affect rocks which have been previously subject to isoclinal folding, although the evidence is not equivocal. Gold is hosted within rocks that seem to record a retrograde greenschist assemblage, overprinting amphibolite grade metamorphism which appears to be related to the Snowshoe Bay intrusion. This indicates that the gold is associated with or younger than the cooling stages of that intrusion, clearly establishing gold mineralization as one of the later temporal events in the regional framework.

The actual mechanism of gold concentration is dependent on the structural, chemical, and metamorphic conditions, all of which are under further consideration. Detailed petrography, combined with geochemistry, should aid in sorting out more complicated relationships. This combined with U-Pb radiometric dating will aid in defining the overall temporal relationships.

ACKNOWLEDGMENTS

The author would like to thank G.R. Cunningham-Dunlop of Consolidated Professor Mines Limited, for allowing access to the property, supplying much appreciated information, and for providing accommodation, and A.J. Troop, Consulting Geologist, for suggestions and criticisms.

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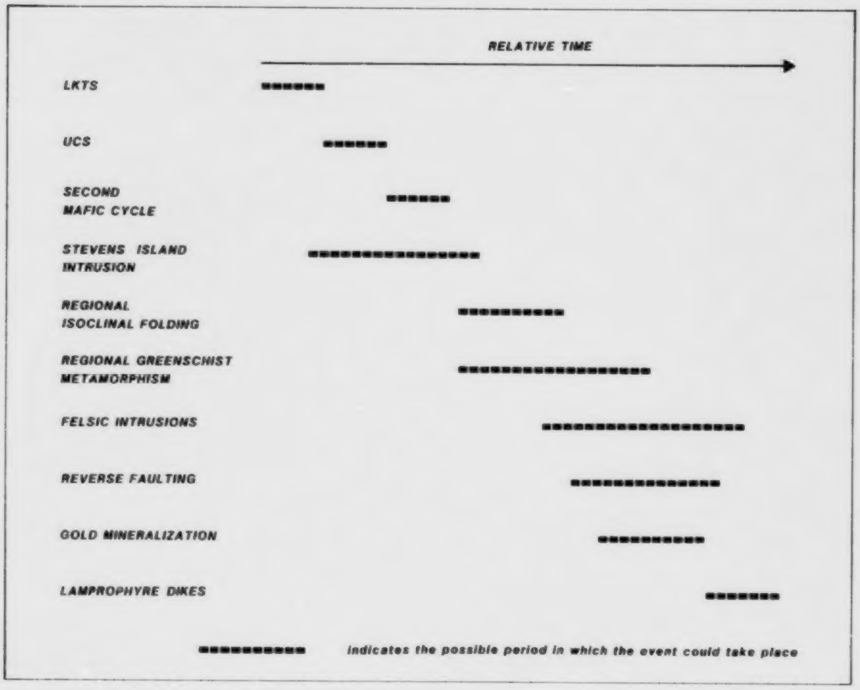

Figure 2. *The relative timing of volcanic, intrusive and tectonic events determined from field relationships. (Project 42.)*

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S43. Geological Setting of Gold Mineralization in Central Moss Township, Shebandowan Greenstone Belt, Northwestern Ontario

Lesley Chorlton

Geologist, Mineral Deposits Section, Ontario Geological Survey, Toronto.

This project was funded equally by the Governments of Canada and Ontario under the Northern Ontario Rural Development Agreement (NORDA).

INTRODUCTION

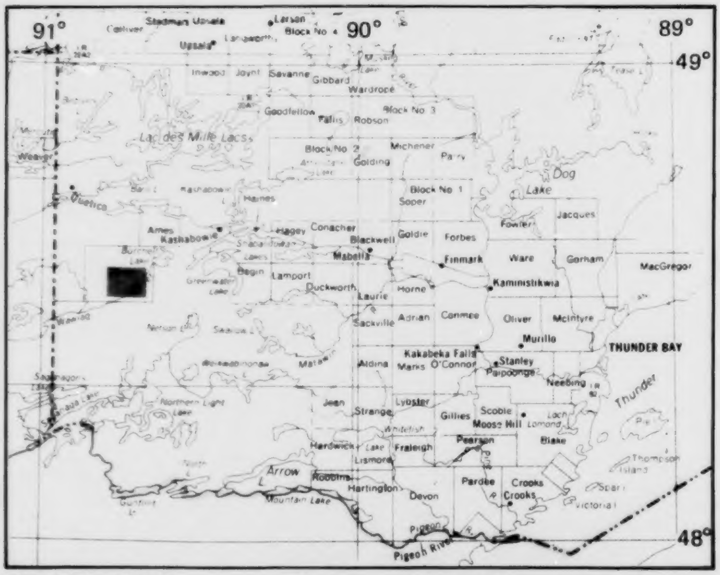
The focus of regional geological investigation in 1985 for the Shebandowan gold project (Chorlton and Brown 1984) was the terrain surrounding the abandoned Huronian (Ardeen, Moss, Kerry) Gold Mine in Moss Township. The Huronian Mine produced 29 629 ounces of gold and 170 463 ounces of silver between 1932 and 1936 (Schneiders and Dutka 1985) before declaring bankruptcy due to the high cost of recovery (Harris 1970). Numerous exploration trenches and gold showings are located southwest of the mine, on ground presently held by Huronian Mines Limited. In addition, a gold property on Snodgrass Lake, 3 km east of the Huronian Mine area, is currently being explored jointly by Tandem Resources Limited and Storiman Exploration Limited (The Northern Miner Press; September 20, 1984).

The area is approximately 85 km west of Thunder Bay, and is now accessible via recent Great Lakes Paper Company roads, reached by travelling 112 km west from Thunder Bay via Highway 11 to the junction of Highway 802, and driving south along Highway 802 for 5.9 km to the junction of the main Great Lakes Paper Company road. The Hermia Lake Road (Figure 1) intersects this road 10.1 km south of the junction. The Spruce Island Road, which leads to the Snodgrass gold property, joins the Hermia Lake Road at 3.7 km, and the corduroy road leading to the Huronian Mine intersects it at 4.4 km.

Watson (1929) first summarized the mineralization and setting of the Huronian Gold Mine, including a reconnaissance map of the surrounding region, the history of exploration and development to date, and a description of the metallogeny of the gold-bearing veins. A 1:31 680 scale regional map by Harris (1970) covered the Huronian Mine and Snodgrass areas. Harris (1970) included a detailed map of the Huronian Mine site itself, as well as an updated history of exploration and development for all known showings of economic mineralization. The purpose of the current investigation is to document the rock types, structure, intrusive history, alteration patterns, and mineralization based on 1:3 750 scale mapping of a northeast-trending rectangular area through the Huronian Mine and less detailed mapping of the area on the western side of Snodgrass Lake. This report is preliminary, and precedes geochemical results and petrographic examination which will be incorporated in the interpretation on the modes and controls of gold mineralization.

GEOLOGY

The geological setting is one in which the oldest rocks, largely metavolcanics, were affected by numerous ductile shear zones and faults, concentrated along certain linear deformation zones (Durocher and Hugon 1983). Along with various post-volcanic, and probably synkinematic intrusions, the metavolcanics


91°
90°
89°
49°
48°
Upsala
Savanne
Gibbard
Wardrope
Goodfellow
Robson
Lac des Mille Lacs
Michener
Golding
Dog Lake
Jacques
Conacher
Blackwell
Goldie
Forbes
Mabella
Finmark
Ware
Gorham
MacGregor
Lamport
Duckworth
Horne
Kaministikwia
Laurie
Adrian
Conmee
Oliver
McIntyre
Sackville
Murillo
THUNDER BAY
Kakabeka Falls
O'Connor
Stanley
Neebing
Strange
Gillies
Scoble
Loch Lomond
Hardwick
Fraleigh
Pearson
Blake
Arrow L.
Hartington
Devon
Pardee
Crooks
Pigeon River
Thunder Bay

LOCATION MAP Scale : 1 : 1 548 000 or 1 inch to 25 miles

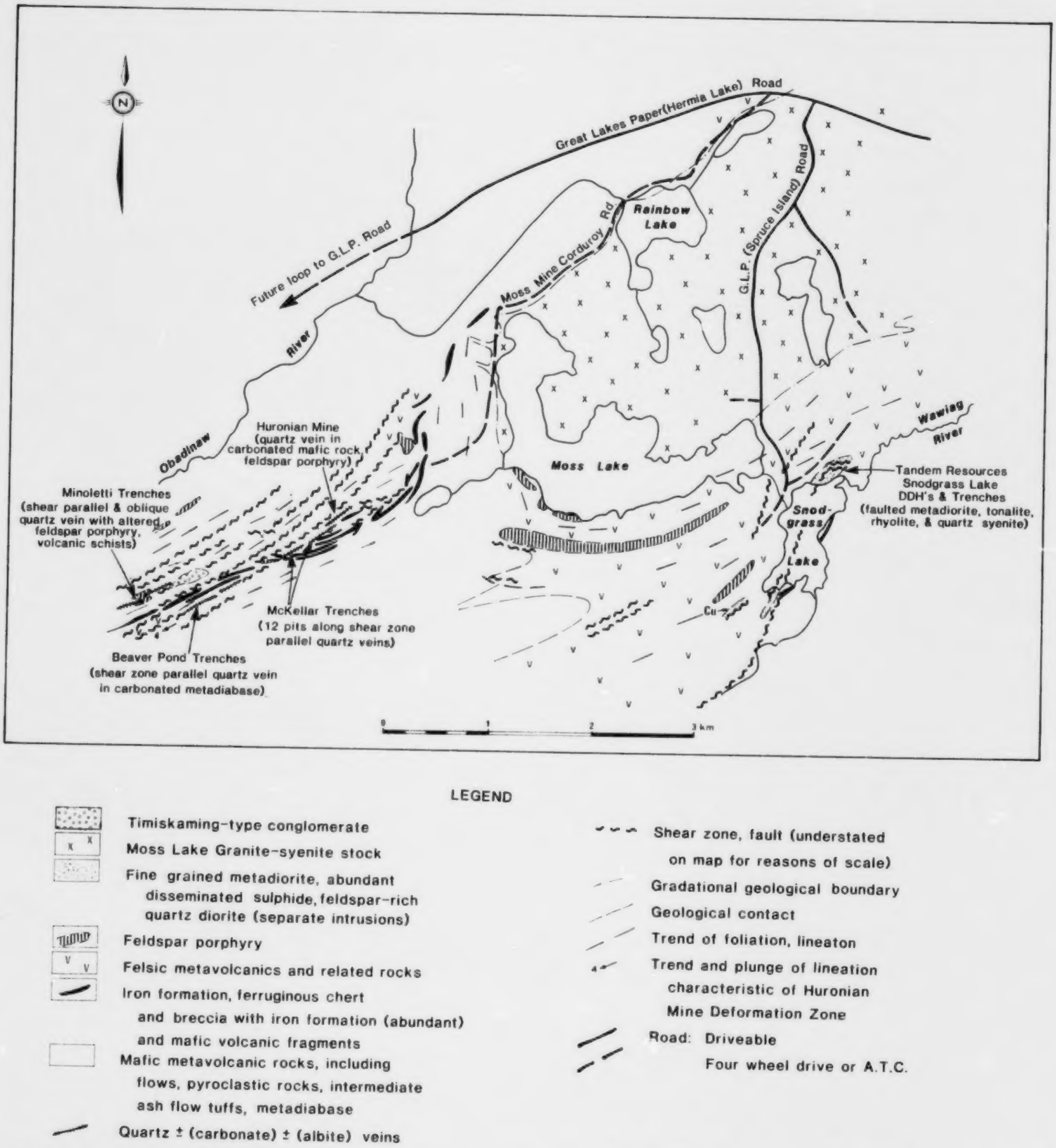

N
Great Lakes Paper (Hermia Lake) Road
Future loop to G.L.P. Road
Obadinaw River
Moss Mine Corduroy Rd.
Rainbow Lake
G.L.P. (Spruce Island) Road
Moss Lake
Wawiag River
Snodgrass Lake
Cu
Huronian Mine (quartz vein in carbonated mafic rock, feldspar porphyry)
Minoletti Trenches (shear parallel & oblique quartz vein with altered feldspar porphyry, volcanic schists)
McKellar Trenches (12 pits along shear zone parallel quartz veins)
Beaver Pond Trenches (shear zone parallel quartz vein in carbonated metadiabase)
Tandem Resources Snodgrass Lake DDH's & Trenches (faulted metadiorite, tonalite, rhyolite, & quartz syenite)
0
1
2
3 km
LEGEND
Timiskaming-type conglomerate
Moss Lake Granite-syenite stock
Fine grained metadiorite, abundant disseminated sulphide, feldspar-rich quartz diorite (separate intrusions)
Feldspar porphyry
Felsic metavolcanics and related rocks
Iron formation, ferruginous chert and breccia with iron formation (abundant) and mafic volcanic fragments
Mafic metavolcanic rocks, including flows, pyroclastic rocks, intermediate ash flow tuffs, metadiabase
Quartz ± (carbonate) ± (albite) veins
Shear zone, fault (understated on map for reasons of scale)
Gradational geological boundary
Geological contact
Trend of foliation, lineaton
Trend and plunge of lineation characteristic of Huronian Mine Deformation Zone
Road: Driveable
Four wheel drive or A.T.C.

Figure 1. Sketch map showing major geological elements and location of known gold occurrences in the Huronian Mine-Snodgrass Lake area, central Moss Township. (Project S43.)

were intensely altered and veined locally within these zones before the emplacement of a leucogranitic to syenitic intrusion north of Moss Lake. Deformation along the southeastern margin of the stock may have outlasted its emplacement. The oldest rocks include the mafic to intermediate metavolcanics, iron formation, and metadiabase which predominate in the Huronian Mine area, and felsic metavolcanics which predominate near Snodgrass Lake (Figure 1). Polymictic conglomerate northeast of the Minoletti trenches (Figure 1) may be significantly younger than these metavolcanics. Synkinematic intrusions, most of which on a local scale are noticeably affected by regional deformation and alteration within the main mineralized areas, consist of hornblende porphyry and feldspar porphyry in the western part of the area, and metadiorite, hornblende (± quartz) syenite, and feldspar porphyry dikes next to Snodgrass Lake.

MAFIC METAVOLCANICS

Massive to pillowed metabasalt with interbedded pillow breccia, and pyroclastic breccia to tuff-breccia passing into extensive intermediate ashflow tuffs are exposed in the western part of the area. Most metabasalts are either aphyric or contain altered mafic phenocrysts, although finely feldspar-phyric locally. Flows vary from moderately to highly vesicular and/or amygdaloidal. Magnetite-rich interpillow and pillow breccia matrix is exposed near the Huronian Mine. Angular fragments of ferrugenous chert magnetite-rich iron formation, and either pure chert or vein quartz occur locally within the mafic breccia.

IRON FORMATION

Iron formation includes well banded magnetite-chert (BIF), weakly magnetic, massive chert (lean IF), and massive magnetite rock. All are commonly associated spatially with a breccia consisting of widely varying proportions of iron formation, pure siliceous chert, fragmented greenstone and amygdule filling. The primary nature of the transition from intact iron formation into the fragmental iron formation may be either lateral, vertical, or both. It is tentatively suggested that the fragmentation may be related to eruptive activity responsible for the mafic pyroclastic breccia described above.

Iron formation is structurally repeated in the map area, and because of relatively high competency, is tectonically fragmented within shear and fault zones during influxes of carbonate and quartz. Pyritization commonly accompanies this vein quartz, and the iron formation becomes nonmagnetic. Away from ductile shear zones, where strain is moderate at most, fractures are flooded with fine grained silica, although pyrite is lacking.

METADIABASE

Metadiabase occurs as elongate bodies distinguished here from massive metabasalts on the basis of uniform, subophitic texture. They vary from very fine to medium grained, and some exposures also show uralitized ferromagnesian phenocrysts. They are more common within mafic metavolcanic terrains than felsic, and it is conceivable that some bodies may be thick flows rather than intrusions (e.g. Harris 1970). Nevertheless, they are also recorded by Harris (1970) within the Quetico metasedimentary belt to the northwest.

Several narrow strips of shear-bounded metadiabase occur along the central part of the area mapped west of Moss Lake, within the ductile deformation zone. To the southeast of this zone, the metadiabases become more extensive. It is suggested here that the metadiabase strips are actually tectonically dissected and transposed segments of only one or two larger intrusions.

FELSIC METAVOLCANICS

Interlayered ignimbrite, feldspathic crystal tuffs, finely quartz- and feldspar-phyric rhyolite and rhyodacite are dominant between Moss and Snodgrass Lake, and north-northwest of the study area. Narrow, highly deformed felsic pods are juxtaposed against mafic rocks southwest of the 'Beaver' trenches within the western ductile deformation zone.

METADIORITE (SNODGRASS AREA)

An intrusion of relatively mafic, fine grained diorite grading locally to more feldspathic tonalite is exposed west of Snodgrass Lake and at the Tandem trenches north of Snodgrass Lake (Figure 1). In the Tandem zone, the diorite cuts felsic metavolcanics, and is in turn cut by feldspar porphyry dikes (in drillcore). All rock types are fractured, and locally sheared. The diorite is charged with pyrite and local chalcopyrite.

HORNBLENDE PORPHYRY

Dikes and small stocks of hornblende porphyry are common, particularly in the western ductile deformation zone. Hornblende phenocrysts are prismatic, and locally extremely fresh. Hornblende-phyric flows are exposed in the Minoletti trenches; hornblende-phyric, vesicular dikes are anomalously abundant nearby. This high concentration may be spatially associated with the conglomerate. This distinctive hornblende-phyric unit also outcrops as far northeast as the Huronian Mine site, and is associated with polymictic conglomerate near the Obadinaw River.

FELDSPAR PORPHYRY

Feldspar and feldspar-quartz porphyry occur as dikes, sills, and small stocks throughout the area mapped. These bodies vary from intermediate to felsic composition. Feldspar phenocrysts consist of plagioclase which are commonly zoned, in contrast to the alkali feldspar phenocrysts of porphyry dikes related to the Moss Lake stock. In some places, the plagioclases are albitized, and very porcelaneous in texture. In others, they are reddened, and/or sericitized.

CONGLOMERATE

Polymictic pebble conglomerate is exposed northeast of the Minoletti trenches (Figure 1), and about 0.8 km to the north. The conglomerate is poorly sorted, and contains rounded to subangular clasts of feldspar porphyry, hornblende porphyry, felsite, and metabasalt. At the Minoletti trenches, over 50% of the clasts in a small conglomerate exposure are derived from the neighbouring hornblende-phyric flow, whereas several texturally similar hornblende porphyry dikes cut the conglomerate to the northeast. This suggests a temporal link between the hornblende porphyry and the conglomerate, reminiscent of the close temporal relationship between the Timiskaming-type sediments and shoshonitic to latitic lavas along the Shebandowan Mine Road in the northern part of the Shebandowan greenstone belt demonstrated by Corfu and Stott (1985).

SYENOGRANITE

The main intrusion of syenogranite is the Moss Lake stock. Quartz-poor, clinopyroxene and/or hornblende, alkali feldspar leucogranite, with accessory magnetite and fluorite is the most common rock type in the southern part of the stock. Syenite is exposed mainly

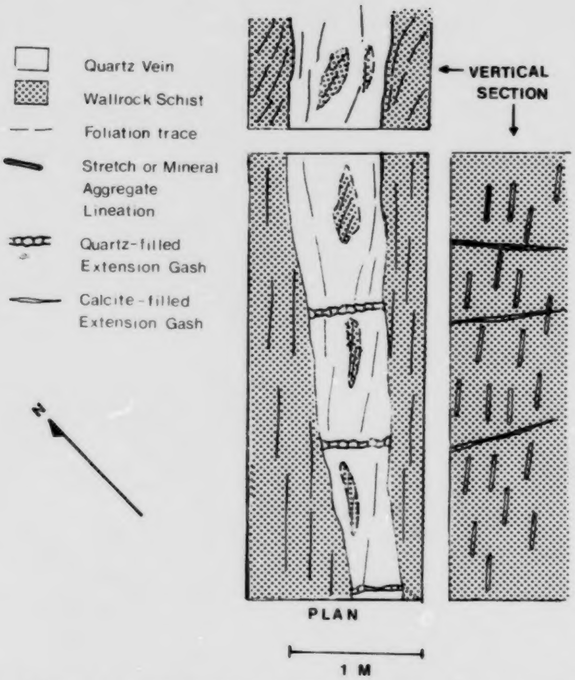

Quartz Vein
Wallrock Schist
Foliation trace
Stretch or Mineral Aggregate Lineation
Quartz-filled Extension Gash
Calcite-filled Extension Gash
N
VERTICAL SECTION
PLAN
1 M

***Figure 2.** Structural relations of shear zone parallel, auriferous, quartz veins in the Huronian Mine area. (Project S43.)*

in the southeast to northeast parts (outside the area mapped), where exposures are locally composite, with leucosyenite intruding more mafic syenite. Sanidine-phyric dikes locally cut more coarse grained leucogranite, and inject the surrounding metavolcanic terrain away from the contact. Apophyses into the host rocks in the contact zone (below) more commonly consist of fine grained, sugary leucogranite to leucosyenite, associated with pegmatite in places.

The Moss Lake stock exhibits a wide contact zone, varying irregularly from enclaves of metavolcanic rock in the granitoid rock to irregular apophyses and planar dikes of granitoid into hosts. In the west-southwest contact zone, these intrusions are undeformed and abruptly truncate early fabrics and tectonic layering; in many places dikes were emplaced along extension fractures nearly normal to the regional stretching direction. In the southeast, the syenogranite dikelets generally cut acutely counterclockwise to the strong, sinistral shear foliation of the host rock, and are themselves weakly deformed with the same shear sense. This suggests that the main deformation east of Moss Lake outlasted the emplacement of the stock and the main deformation stage west of Moss Lake.

Pink, quartz- and hornblende-phyric syenogranite, more mafic and hornblende-rich than apophyses of the Moss Lake stock intrudes the metadiorite in the Tandem zone at Snodgrass Lake. Hornblende-phyric syenite is also exposed farther south on the western shore of the lake.

Albitite pods and stringers are commonly associated with auriferous mineralization in the Minoletti and Beaver trenches.

STRUCTURE

Exposures in central Moss Township do not display evidence for a full sequence of D_1 to D_3 structural events as defined by Bau (1975, 1979), Stott and Schwerdtner (1981), and Morton (1982) (summarized *in* Chorlton and Brown 1984). In particular, Morton (1982) found evidence for shallowly reclined or recumbent, nappe-like structures in the Lake Shebandowan area to the northeast. However, schistosity, shear and fault planes, and bedding markers in IF, ashflows, and pillow-pillow breccia sequences are presently steeply dipping, and associated with folds with steep axial planes, and/or with steeply dipping shear-fault planes. The attitude and style of this deformation corresponds to the post-D_1, predominantly D_2 deformational episodes of regional workers, although D_1 undoubtedly affected the crust in this area.

Thus, deformational strain (post regional D_1) is concentrated: (1) within a prominent, northeast-trending ductile deformation zone, consisting of numerous parallel, northeast-trending shear zones and faults in the west (Figure 1); and (2) in less numerous shear zones and minor faults associated with a major fault through Snodgrass Lake. Away from these zones, evidence of penetrative regional strain is sparse.

Between discrete shear zones of the western deformation zone, strain may also be weak or absent. Generally, a northeasterly striking, northwesterly dipping schistosity is developed which swings counterclockwise, steepens, and intensifies into the ductile shear zones. Stretching lineations (stretched volcanic clasts, vesicles, and mineral aggregates replacing ferromagnesian phenocrysts) are most prominent within the shear zones, and commonly plunge very gently to the southwest. The geometry of tectonic fabrics thus suggests largely sinistral shear, with a very minor southeast side up component.

Some of the shear/fault zones are marked by zones of intense fracture, particularly where more competent, felsic, or silicified volcanic rocks are affected. Next to several fault zones, quartz ribbons (dilation veins) several millimetres to a centimetre wide which have cut across the shear zone, have been folded, fragmented, and displaced with sinistral offset.

Polymetallic quartz veins from several centimetres to over a metre wide occur along several of the ductile shear zones (Figure 2). Where feldspar porphyry dikes oblique to the structural trend are caught up in these shear-vein systems and folding, they may site subsidiary veins within tight fold noses or along attenuated limbs (Figure 3). Individual shear-vein systems are approximately 200 m long, and are responsible for the gold mineralization in the western part of the study area. All of the veins display quartz- and carbonate-filled, extension gashes perpendicular to the vein and shear zone (Figure 2), and fragmented and extended pyrite cubes.

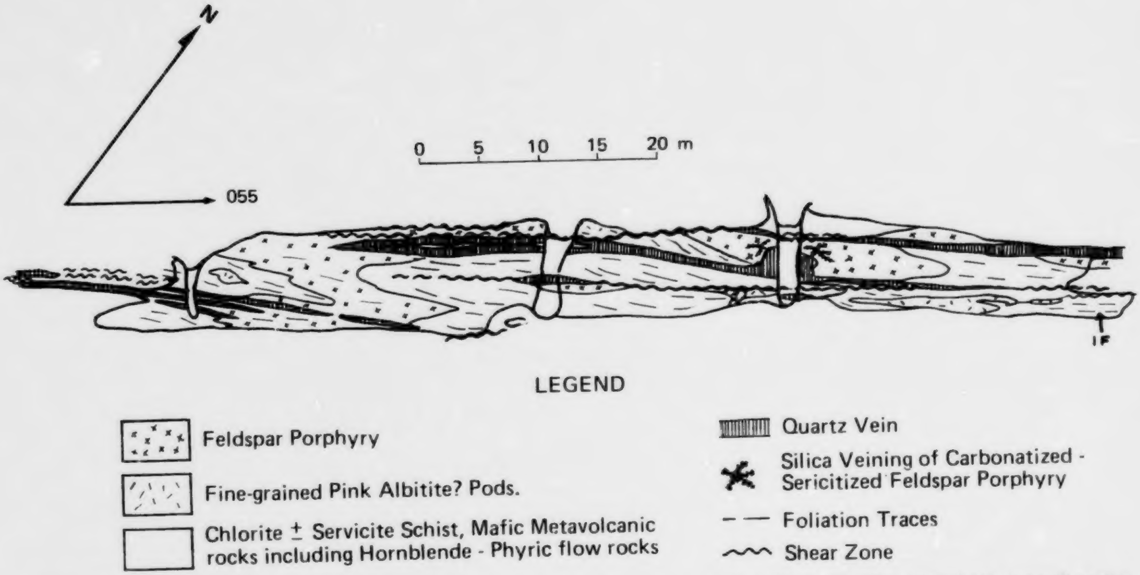

N
055
0 5 10 15 20 m
IF
LEGEND
Feldspar Porphyry
Fine-grained Pink Albitite? Pods.
Chlorite ± Servicite Schist, Mafic Metavolcanic rocks including Hornblende - Phyric flow rocks
Quartz Vein
Silica Veining of Carbonatized - Sericitized Feldspar Porphyry
Foliation Traces
Shear Zone

***Figure 3.** Relationship of feldspar porphyry to the shear zones and veining at the Minoletti trench zone, southwestern trenches. (Project S43.)*

Barren, quartz (± tourmaline) stockworks occur in a few of the faults.

On the eastern side of the area, a fault zone marked by calcite-charged sericite-chlorite schists and a wide zone of fracturing extends through Snodgrass Lake. This fault juxtaposes variably silicified and calcified mafic metavolcanics, iron formation, and mafic breccia containing iron formation, chert, and mafic volcanic clasts on the eastern side against largely felsic metavolcanics and intrusive rocks on the west. A mylonite zone within the felsic metavolcanic terrain between Moss and Snodgrass Lake parallels this fault.

Several east-northeast trending minor faults and a locally conjugate set of shear zones, as well as pervasive fracturing have affected rocks exposed at the Tandem outcrop and trenches (Figure 4).

ALTERATION

Ferroan dolomite alteration characterizes the western ductile deformation zone. It either pervades tracts encompassing several discrete shear zones, such as the area of the Huronian Mine, or is concentrated within individual shear zones, such as the Minoletti and Beaver zones to the southwest. Albitite veinlets are common in carbonatized rocks near the margins of mineralized veins. Feldspar porphyries which are incorporated into the shear-vein systems are highly iron dolomitized, sericitized, and traversed by finely pyritiferous albite-quartz veinlets. Green sericite also characterizes these porphyries. Late stage, calcite-filled fractures occur both within the main mineralized shear zones and away from them, particularly in sheared metadiabase.

Sheared and fractured rocks close to Snodgrass Lake are enriched in calcite. Calcite-filled fractures are abundant in fractured metadiorite and feldspar porphyry at the Tandem trenches.

GOLD MINERALIZATION

Gold mineralization in the western part of the area is associated with the large quartz (± dolomite and/or albite) veins and vein systems sited along several of the shear zones. Four of these systems have been trenched: (1) two closely spaced, parallel shears of the McKellar trenches, immediately southwest of the Huronian Mine; (2) the Beaver zone; and (3) the Minoletti zone. The McKellar and Minoletti veins contain polymetallic sulphide mineralization (pyrite, galena, chalcopyrite, and local sphalerite), and an unidentified grey metallic mineral which may be a telluride, similar to the Huronian Mine vein (Watson 1929; Harris 1970). Host rocks near vein margins are pyritized. Feldspar porphyry is particularly well mineralized adjacent to veins. In the Minoletti trenches, feldspar porphyry is caught up in several discrete shear zones, tightly folded, and fragmented by faulting (Figure 3). The tight hinge and attenuated northwestern limb of one of the folds hosts multiple quartz veins (Figure 3), and another fragment is likewise traversed by many small quartz veins and fracture fillings. The latter is intensely altered (carbonate-sericite-albite-quartz) and mineralized with fine grained pyrite. Preliminary geochemical assays from 1984 show this rock to be auriferous, as is altered and pyritized porphyry in the Huronian Mine (Watson 1929), and altered porphyry along the margins of the McKellar veins. The quartz vein of the Beaver zone contains minor iron carbonate, pyrite and chalcopyrite, with sulphide mineralization disseminated within 5 to 10 cm of the vein.

At the Tandem trenches and outcrop on Snodgrass Lake (Figure 4), pyrite and chalcopyrite min-

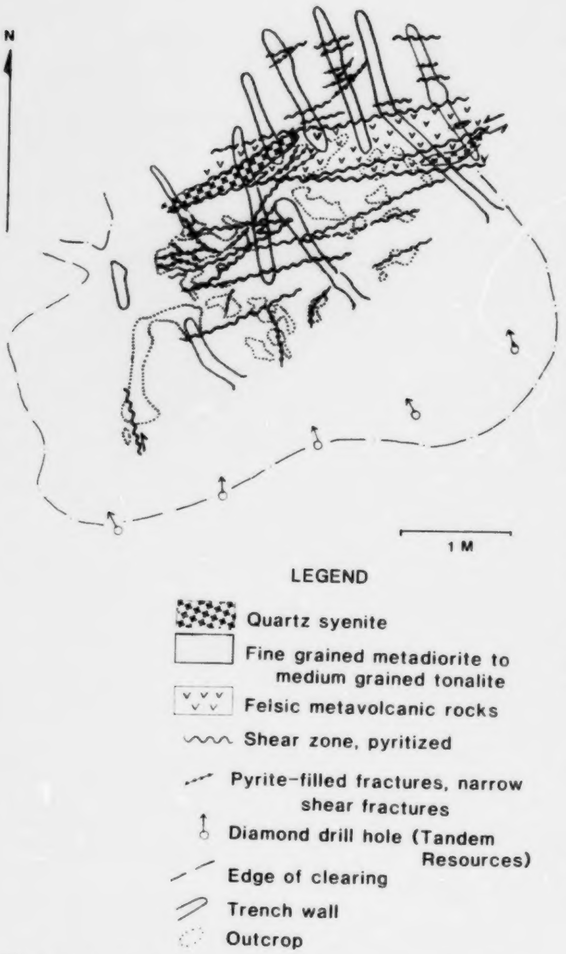

N
1 M
LEGEND
Quartz syenite
Fine grained metadiorite to medium grained tonalite
Felsic metavolcanic rocks
Shear zone, pyritized
Pyrite-filled fractures, narrow shear fractures
Diamond drill hole (Tandem Resources)
Edge of clearing
Trench wall
Outcrop

Figure 4. *Geology of Storimin Exploration-Tandem Resources exposure at trenched area north of Snodgrass Lake. (Project S43.)*

eralization is visible in: (1) narrow ductile shear zones, some with quartz and calcite veining and some with only calcite; (2) accompanied by calcite in numerous small and large fractures; and (3) disseminated in the metadiorite and the quartz-hornblende syenite, with only minor disseminated pyrite in the feldspar-phyric tonalite. Pyrite, chalcopyrite, and malachite were noted in the metadiorite exposure southwest of the trench area (Figure 1).

CONCLUSIONS

Two contrasting styles of gold-sulphide mineralization are displayed in the Huronian Mine and Snodgrass area of central Moss Township. In the west, gold occurs with sulphide mineralization and telluride within and next to quartz veins sited along major shear zones, and in subsidiary veins within folded feldspar porphyry and quartz-flooded, intensely altered porphyry fragments caught up in the same shear-vein systems. At the Snodgrass Lake Tandem property, gold occurs in metadiorite and subordinate quartz syenite with disseminated, fracture-filling, and shear zone-filling pyrite chalcopyrite. The deformation of these rocks is predominantly related to the Snodgrass Lake fault zone.

Polymictic conglomerate and hornblende-phyric volcanic flows are exposed along the Huronian Mine belt, and may represent 'Timiskaming type' fault-controlled magmatism and sedimentation. They are deformed by continuing faulting and shearing, and are among the hosts to auriferous veining in the Minoletti zone.

ACKNOWLEDGMENTS

The author thanks Joy Williams and Gary Kitchener for their invaluable field assistance. The help and advice of Dr. G. Patterson, Dr. P. Thurston, J. Scott, B. Schneiders, J. McNichol, P. Corbett, F. Kristjansson, and S. Ringuis of the Ministries of Northern Affairs and Mines, and Natural Resources is gratefully acknowledged, as is the cooperation of the proprietors of Huronian Mines Limited, Tandem Resources Limited, Storiman Exploration Limited, and Kashabowie River Resort.

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S44. A Re-Examination of Some Mineral Occurrences in the Shebandowan Greenstone Belt, Northwestern Ontario

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This project was funded equally by the Governments of Canada and Ontario under the Northern Ontario Rural Development Agreement (NORDA).

INTRODUCTION

The Shebandowan greenstone belt has been the target of sporadic exploration since the development of the Huronian (or Moss) Mine in the early 1870s. Interest has recently been refocused on the area as a result of reports of favourable gold intersections from diamond drilling on several known occurrences. Subsequent to this renewal of interest, a program of regional geological synthesis and property examination was initiated (Chorlton and Brown 1984). The objective was to gain insight into factors controlling the siting of gold mineralization in order to propose useful guidelines for exploration.

Property re-examination was carried out concurrently with the regional geological study conducted by Lesley Chorlton (Chorlton and Brown 1984; Chorlton, this volume). Thirty-one properties (Figure 1) were visited during the 1984 and 1985 field seasons. Old workings present on the properties have been located and described. Representative samples of the mineralized zones were collected for analysis and minor geological mapping of the surrounding area was carried out.

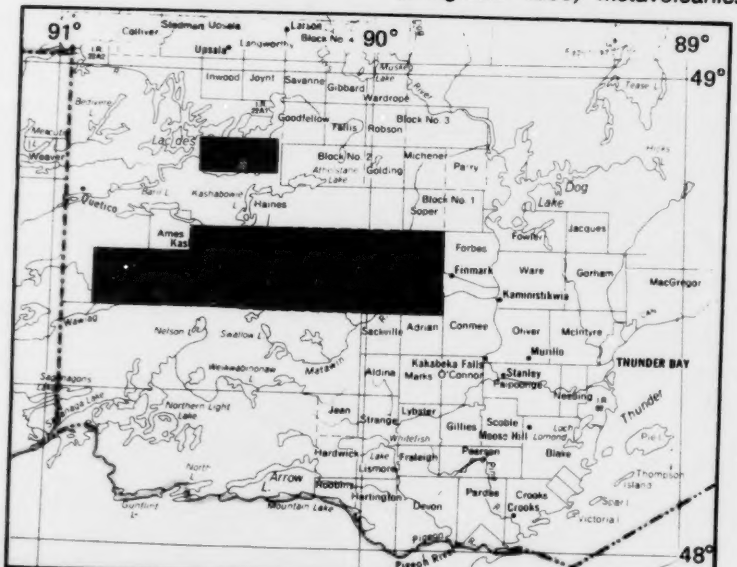
LOCATION AND ACCESS

The Shebandowan greenstone belt is bounded by Longitudes 89°30'W to 91°20'W, and Latitudes 48°00'N to 48°55'N. The majority of the mineral occurrences are concentrated in the Shebandowan Lakes area, approximately 90 km west of Thunder Bay. Access to many of the properties is facilitated by the presence of Highway 11, which runs through the northern part of the belt, and by numerous secondary and logging roads. Properties not readily accessible by road can usually be reached by flagged trails or by boat.

GENERAL GEOLOGY

The regional geology has been summarized previously (Chorlton and Brown 1984) and only a brief discussion is presented here.

Mafic to felsic metavolcanics of greenschist facies metamorphic grade, cut by many generations of felsic and mafic intrusions, predominate in the Shebandowan greenstone belt. Outcrops of these units consist of massive to pillowed flows, locally brecciated, with less abundant tuff and agglomerate. Two groups of metasediments occur in the area. The Kashabowie group, in the northern part of the belt, consists mainly of biotite-feldspar-quartz schist grading into migmatite (Hodgkinson 1968). The metamorphic grade is generally higher in these rocks than in the rocks to the south (Hodgkinson 1968). Several inliers of mainly coarse to medium grained clastic metasediments constitute the second group of sediments. Associated with them are shoshonitic to latitic (Shegelski 1980) metavolcanics, distinct from the


91°
90°
89°
49°
48°
Upsala
Larson
Langworthy
Inwood
Joynt
Savanne
Gibbard
Wardrope
Goodfellow
Fallis
Robson
Block No 3
Block No 2
Golding
Michener
Parry
Block No 1
Soper
Haines
Kashabowie L.
Dog Lake
Fowler
Jacques
Ames
Forbes
Finmark
Ware
Gorham
MacGregor
Kaministikwia
Sackville
Adrian
Conmee
Oliver
McIntyre
Murillo
THUNDER BAY
Kakabeka Falls
Marks
O'Connor
Stanley
Neebing
Aldina
Jean
Strange
Lybster
Gillies
Scoble
Moose Hill
Blake
Hardwick
Fraleigh
Pearson
Lismore
Arrow L.
Robbins
Hartington
Devon
Pardee
Crooks
Pigeon River
Mountain Lake
Gunflint L.
North L.
Northern Light Lake
Saganagons
Quetico
Nelson L.
Weaver
Thunder Bay
Pie I.
Thompson Island
Spar I.
Victoria I.

LOCATION MAP

Scale : 1 : 1 548 000 or 1 inch to 25 miles

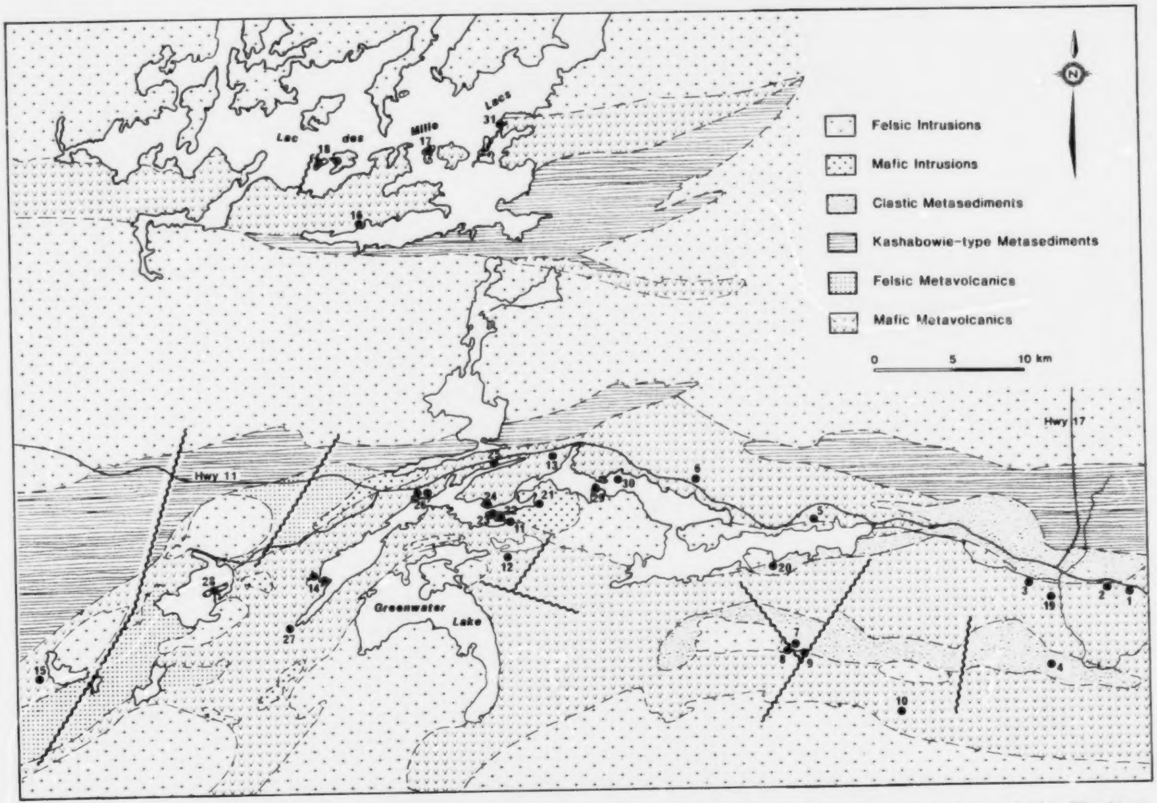


Figure 1. General geology and location of properties visited in the Shebandowan greenstone belt. (Project 44.)

metavolcanics mentioned above. This association is most extensive in the eastern part of the belt (Pye and Fenwick 1965) but has also been recognized recently (Chorlton, this volume) in the west. It is thought that these rocks are related to a relatively advanced stage of Archean crustal thickening (Shegelski 1980). Iron formation is associated with the older mafic metavolcanics, and with the second group of metasediments.

Although few folds are visible in the older metavolcanics of the belt, tight isoclinal folds in two of the metasedimentary inliers have been documented by Brown (in preparation). Numerous steeply dipping shear zones, and several major faults of northwesterly and northeasterly strike are present. There is evidence of both dextral and sinistral sense of displacement along the faults.

Mineral occurrences in the Shebandowan greenstone belt consist primarily of copper, gold, and silver. Of these, the emphasis during this project was placed on gold. The most significant field observations for the occurrences visited are summarized in Table 1. Field observations have been supplemented by data from the assessment files in the Toronto and Thunder Bay Offices, as well as from other sources (Giblin 1964; Harris 1970; Hodgkinson 1968; Kaye 1967; Morin 1973; Schnieders and Dutka 1985; Thomson 1936).

DISCUSSION

In generalizing the features of the occurrences listed in Table 1, several similarities and contrasts become apparent. Carbonatization and silicification of the host rocks are common features. Carbonatization occurs in the form of concentrations of calcite, and, locally, iron-rich carbonate in veins and veinlets with or without quartz, and as patchy overprints. Silicification manifests itself as veins or veinlets, as an overall silicification of the host rocks, or as siliceous, or 'cherty' fracture or breccia matrix fillings.

The most obvious dissimilarity is in the overall structural style exhibited by the occurrences in the eastern part of the belt compared to those in the western part. In the eastern properties, intense fracturing and brecciation of the host rocks are common features. Shearing, where present, is only moderately developed, and cleavage and schistosity are prominent on a local scale only. Mineralization here is predominantly associated with quartz enrichment, either in the form of veins and veinlets, or in the matrix of brecciated host, and finely disseminated in altered rocks.

In contrast to this, the properties in the western part of the belt most often display well developed ductile shear zones associated with the mineralization. Examination of the geology surrounding these occurrences shows cleavage and schistosity are bet-

TABLE 1. SUMMARY OF THE GEOLOGY AND STRUCTURE OF THE PROPERTIES VISITED DURING 1984 AND 1985. (PROJECT S 44).

Name of Occurrence (Commodity)	Host Rock (Associated sulphides)	Significant Structural Features	Mode of Mineralization of Sulphides	Additional Mineral Association	References
Gold Occurrences					
Eastern Properties					
Dawson Road Lots:					
1. East Zone (Au, Ag) 2. West Zone (Au, Ag)	a. Chert breccia b. Carbonatized volcanic rock. (Py)	Fracturing and brecciation.	Fracture filling. Quartz veinlets and stringers. Minor disseminations.	Fe-carbonate pervasive. Calcite filling fractures. Green Mica. Silicification.	6,7
3. Kasper (Au, Ag)	a. Diorite (Py) b. Silicic metavolcanic rocks. (Py)	Weak foliation. Minor fracture cleavage. Brecciation. Superimposed shearing near diorite contact.	Accompanying irregular quartz veins. Disseminated. Shearing concentrated. Quartz veins near diorite contact.	Fe-carbonate and calcite disseminated and filling fractures. Silicification? - (metavolcanic rocks).	1
4. Kukkee (alt. Mattawin River) (Au, Ag, reported Pt, Ni)	Magnetite-chert IF associated with metagreywacke and polymictic sedimentary breccia. (Py, cp, minor gal)	Fracturing.	Fracture filling. Quartz and quartz-carbonate veins along fractures.	Fe-carbonate and calcite along fractures and veins. Hematization.	1
Central Properties					
5. Band-Ore (Au, Ag)	Schistose felsic porphyry. Mafic to intermediate metavolcanics. (Py, cp)	Shearing. Development of carbonatized, sericitized schist.	Quartz and quartz-carbonate veins. Shearing concentrated.	Fe-carbonate disseminated and concentrated along foliation planes.	1,5,6
6. J.F. West (Au)	Felsic porphyry. (Py, minor cp)	Fracturing. Shearing at southern margins of porphyry. Minor faulting.	Quartz and quartz-carbonate veins.	Fe-carbonate disseminated and in quartz veins. Calcite filling fractures and in veins with epidote.	1
7. Gold Creek. Central Duckworth Township (Au, Ag, Cu, Pb)	Felsic, feldspar-phyric intrusives. (Py, cp, gal)	Moderate fracturing.	Disseminated. Irregular quartz and quartz-carbonate veins.	Fe-carbonate and calcite filling fractures.	6
8. Penziwol (Au, Ag, Cu, Pb)	Felsic, feldspar-phyric intrusives. (Py, gal, po, cp)	Moderate schistosity. Moderate fracturing.	Fracture filling. Quartz veins. Disseminated.	Fe-carbonate disseminated. Veinlets of epidote. Bleaching of host at margins of quartz veins. Silicification?	

TABLE 1 continued

Name of Occurrence (Commodity)	Host Rock (Associated sulphides)	Significant Structural Features	Mode of Mineralization of Sulphides	Additional Mineral Association	References
9. Scali (Au, Ag)	Felsic, feldspar-phyric intrusive. Mafic schists. (Py)	Fracturing of hosts and veins.	Quartz and quartz-carbonate veins.	Calcite in quartz veins.	6
10. Jalna Resources. Southeast Duckworth Township (Au, Ag)	Sericitized, silicic metavolcanics. (Py)	Fracturing. Superimposed lineation.	Quartz veins. Disseminated.	Sericiate, tourmaline, patchy calcite. Green mica.	1
Western Properties					
11. Lake Shebandowan Prospect (Au)	Mafic schists. Diorite. (Py)	Fault contact between rocks.	Fracture filling. Irregular quartz veins and stringers. Disseminated.	Calcite disseminated. Epidote veinlets.	1
12. Andowan (Au, Ag, Cu)	Mafic schists. Felsic porphyry. (Py, asp, gal)	Shearing.	Irregular quartz veins. Shearing concentrated.	Fe-carbonate shearing concentrated. Epidote veinlets. Silicification.	3,6
13. Ray Smith (Au, Cu, Zn, Ag)	Silicic metavolcanics. Felsic porphyry. (Py, cp, gal, sl)	Faulting. Fracturing.	Fracture filling. Quartz vein. Disseminated.	Calcite filling fractures.	1,6
14. Ritchie Estate (Au, Cu, Ag)	a. Mafic schists. (Py, cp)	Shearing. Folding.	Disseminated. Shearing concentrated. Quartz veins, parallel to foliation.	Fe-carbonate and calcite disseminated, fracture filling and in quartz veins. Green mica with syenite. Silicification at margin of quartz veins.	
(Au,Cu,Ag,Mo)	b. Syenite intruding metagabbroic and mafic schists. (Py, cp)	Discrete zones of shearing. Fracturing.	Disseminated. Fracture filling. Quartz veins.	Fe-carbonate and calcite disseminated, fracture filling and in quartz veins. Green mica with syenite. Silicification at margin of quartz veins.	
15. Moss Mine (Au, Ag, Cu, Pb)	Mafic schists. (Cp, py, gal, sl)	Shearing	Quartz vein associated with discrete zones of shearing.	Fe-carbonate. Calcite filling fractures.	2,6

TABLE 1 continued

Name of Occurrence (Commodity)	Host Rock (Associated sulphides)	Significant Structural Features	Mode of Mineralization of Sulphides	Additional Mineral Association	References
Lac des Mille Lacs Area Properties					
16. Bolton Bay (Au, Ag, Ni)	Mafic to felsic metavolcanics. (Py, cp, bornite)	Brecciation. Superimposed shearing. Minor fracturing.	Quartz veins. Breccia matrix. Disseminated.	Fe-carbonate and calcite disseminated. Calcite filling fractures. Sericitization. Silicification?	4,6
17. Case Island (Au, Ag)	Mafic metavolcanics. Metagabbro. (Py)	Shearing.	Quartz veins associated with discrete zones of shearing. Disseminated	Fe-carbonate and calcite disseminated. Green mica. Silicification?	4,6
18. Shaft and Tunnel Islands (Au, Ag, Ni)	Mafic to felsic metavolcanics. (Py, po, cp)	Brecciation. Superimposed shearing.	Breccia matrix.	Fe-carbonate fracture filling and disseminated.	4
Copper Occurrences					
19. Shabaqua (Cu, Au, Ag)	Mafic to intermediate metavolcanics. (Py, cp, malachite)	Fracturing. Brecciation	Fracture filling. With brecciated quartz-veins.	Fe-carbonate with quartz veins. Calcite disseminated and filling fractures. Actinolite veinlets.	
20. Mandarin Mines (Cu, Ni, Au)	Schistose greywacke. (Malachite, gal, py)	Fracturing. Brecciation.	With brecciated quartz-carbonate veins.	Fe-carbonate and calcite disseminated. Bleaching of rock at margins of quartz veins.	1
21. Milkie (Cu, Ni)	Mafic schists. Metagabbro. (Py, cp)	Shearing.	Shearing concentrated. Disseminated-(mafic schists).	Silicification.	
22. Shawmin D (Cu, Ni, Zn)	Mafic schists. Metagabbro. (Py, po, cp, sl)	Shearing.	Shearing concentrated. Disseminated	Calcite disseminated. Sericitization. Local silicification.	1,3
23. Shawmin No. 20 (Cu, Ni)	Metagabbro. Felsic porphyry. (Py, po, malachite, cp)	Sheared contact between hosts. Fracturing.	Fracture filling. Shearing concentrated. Disseminated.	Silicification.	1
24. Whalen (Cu)	Mafic schists. (Py, minor cp)	Shearing. Deformed pyrite.	Shearing concentrated.	Calcite disseminated and in quartz veins. Sericitization.	1,3

TABLE 1 continued

Name of Occurrence (Commodity)	Host Rock (Associated sulphides)	Significant Structural Features	Mode of Mineralization of Sulphides	Additional Mineral Association	References
25. Cornell (Cu, Zn, Au, Ag)	Silicic metavolcanics (Py, cp, sl, po)	Shearing. Faulting.	Shearing concentrated.	Calcite disseminated. Calcite and Fe-carbonate in quartz and quartz-fluorite veins. Sericitization.	3,6
26. Vanguard (Cu, Au, Ag, Zn)	Mafic Schists. (Py, cp, po, sl)	Shearing. Fracturing.	Fracture filling. Shearing concentrated. With quartz veins. Disseminated.	Calcite and Fe-carbonate disseminated. Calcite filling fractures. Silicification.	1,3
27. Moffat (Cu, Au)	Felsic porphyry. Mafic schist. (Py, cp)	Shearing. Fracturing.	With irregular quartz veins. Disseminated.	Fe-carbonate and calcite disseminated. Calcite filling fractures. Veinlets of magnetite.	
28. Goldora (Cu, Ag, Au)	Felsic intrusives. Felsic metavolcanics. (Py, cp)	Shearing. Minor fracturing.	Disseminated.	Calcite disseminated. Magnetite locally filling fractures.	3
Molybdenum Occurrences					
29. Hayne's Shebandowan (Mo, Au, Ag, Cu)	Granite. (Py, cp, mo, gal)	Fracturing.	Quartz veins. Disseminated-(py, cp).	Calcite and Fe-carbonate disseminated and filling fractures.	3
30. Middle Shebandowan Lake Molybdenum (Mo, Au, Ag)	Felsic porphyry intruding metagabbro. (Py, cp, mo)	Shearing.	Quartz veins associated with discrete zones of shearing.	Calcite filling fractures.	1,3
31. Lac des Mille Lacs Molybdenum (Mo, Au)	Porphyritic felsic metavolcanic. (Py, po, mo)	Faulting. Fracturing.	With quartz-carbonate vein.	Calcite in quartz veins.	4

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ter developed than in the east. Crenulations and minor folding of the schists are more common in the western properties, and concentrations of pyrite and chalcopyrite along schistosity planes are a prominent form of mineralization.

The contrasts predominantly reflect an east to west transition from relatively brittle to relatively ductile features at the level of exposed mineralization. Since ductility is enhanced at deeper crustal levels, this contrast could indicate that there has been deeper post-mineralization erosion in the west than in the east, which might also explain the greater extent of younger clastic metasedimentary inliers in the east.

ACKNOWLEDGMENTS

The author would like to thank all of the property owners met in the field, particularly E. Kukkee and R. Thew, who were very generous and helpful in supplying the author with information.

The author would also like to thank Jackie Seguin, John Scott, Doug Parker, and George Patterson of the Resident Geologist's Office in Thunder Bay for providing support during the field seasons, and Bernie Schnieders, of the same office, for helpful discussions.

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45. Geology of the Detour Lake Mine and Surrounding Area

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INTRODUCTION

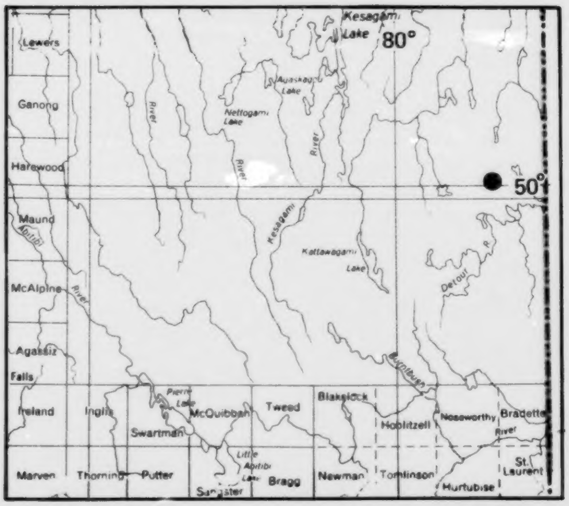
In the author's second year of the study of the Detour Lake gold mine, Abitibi belt, northeastern Ontario, underground mapping of the 120 m level, further mapping of new benches in the open pit, and surface mapping of the area surrounding the mine was carried out. This re-examination of the geological setting of the deposit has led to a better understanding of the controls on mineralization.

Campbell Red Lake Mines Limited, Detour Lake project, recently recalculated the ore reserves and announced them at 10.9 million tons of 0.128 ounce/ton as opposed to the original 30.2 million tons of 0.113 ounce/ton (The Northern Miner Press; January 31, 1985). There will be a gap in production from the time of closing of the pit and starting operation from the shaft which is being sunk to a depth of 655 m (2150 feet).

UNDERGROUND MAPPING

In 1977, in order to evaluate the nature of the mineralization and to obtain a 100-ton bulk sample, Amoco Canada Petroleum Company Limited, drove a 762 m decline to a depth of 120 m. Approximately 2800 m of drifting and crosscutting were carried out on this level. A much more limited amount of development was also done on the 100 m level, which unfortunately was not accessible at the time of this study.

The 120 m level was mapped at a scale of 1:250 and, in addition to new information, because of the three dimensional exposures, better refinement of the geological features mapped in the open pit was achieved. Figure 1 is a simplified map of this level.



LOCATION MAP

Scale : 1 : 1 548 000 or
1 inch to 25 miles

LITHOLOGIES

A full description of most of the lithological units present in the mine is contained in Marmont (1984); the following is a brief account of the lithological units recognized during the underground mapping.

Mafic Metavolcanics

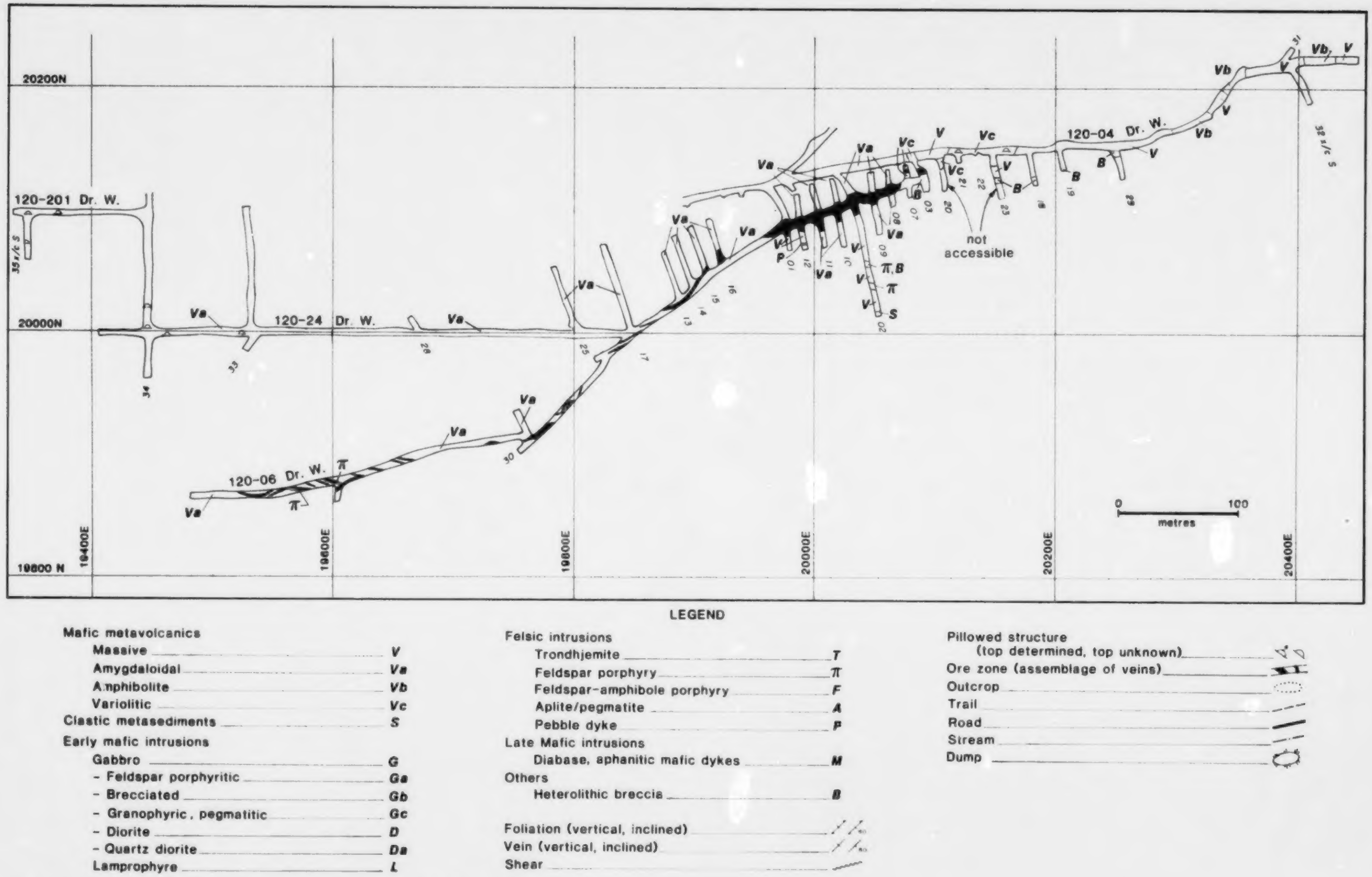
The bulk of the supracrustal rocks consists of massive and pillowed tholeiitic basaltic flows. In some instances, flows are amygdaloidal and the amygdules are either filled with a carbonate, feldspar-quartz assemblage or sulphide, mostly pyrite and pyrrhotite. Two distinctions can be made with respect to the amygdaloidal flows:

1. The sulphide-filled amygdules show a close spatial association with the mineralized sections whereas the silicate-carbonate filled vesicles are found where mineralization is absent.
2. The array of the amygdules away from the ore zones is radial whereas adjacent to mineralized sections, the sulphide-filled blebs are in linear, subparallel arrangement, indicating a stronger degree of lamination and parallelism in the intensely mineralized sections.

In the central part of 120 m level, a distinctive pillowed variolitic unit is present (Figure 1); similar to that of the portal of the decline (*see* Figure 2). The unit consists of a dark green, amphibolitic mafic flow which contains light pink to buff varioles occupying the periphery of the pillow structures. Within the variolitic section, highly stretched amygdules filled with amphiboles, epidote, chlorite, and carbonate show a radial distribution merging towards the centre of the pillow. More swirled patches of variolitic material are also present in the centre of the pillows. The selvages are filled with highly brecciated, hyaloclastic fragments. The pillows are small, amoeboidal, and commonly stretched to lensoidal shapes, to the extent that top determination cannot be made. Petrographic examination may determine the cause of the variolitic texture. If this has formed from immiscible liquids, it would indicate the later stages of volcanism and will be most useful as a marker horizon to aid following the stratigraphy (similar to the V8 and V10 flows in the Porcupine Camp, Ferguson *et al.* 1968). On the other hand, if the variolitic texture is due to devitrification, the rock may not necessarily indicate a specific stratigraphic position in the history of mafic volcanism.

Felsic Intrusions

An array of felsic to intermediate intrusions, consisting of feldspar porphyry, feldspar-biotite porphyry, diorite porphyry, and aplitic/pegmatitic dikes, constitute the main late intrusive phases in the mine area (Marmont 1984). However, in the course of underground mapping a new unit, identified as a "pebble dike", was encountered (Unit P, Figure 1). The rock


20200N
20000N
19800 N
19400E
19600E
19800E
20000E
20200E
20400E
120-201 Dr. W.
35 x/c S
120-24 Dr. W.
120-06 Dr. W.
120-04 Dr. W.
32 x/c S
not accessible
0
100
metres
V
Va
Vb
Vc
B
π
π, B
S
P
01
02
03
07
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14
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22
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LEGEND
Mafic metavolcanics
Massive V
Amygdaloidal Va
Amphibolite Vb
Variolitic Vc
Clastic metasediments S
Early mafic intrusions
Gabbro G
- Feldspar porphyritic Ga
- Brecciated Gb
- Granophyric, pegmatitic Gc
- Diorite D
- Quartz diorite Da
Lamprophyre L
Felsic intrusions
Trondhjemite T
Feldspar porphyry π
Feldspar-amphibole porphyry F
Aplite/pegmatite A
Pebble dyke P
Late Mafic intrusions
Diabase, aphanitic mafic dykes M
Others
Heterolithic breccia B
Foliation (vertical, inclined)
Vein (vertical, inclined)
Shear
Pillowed structure (top determined, top unknown)
Ore zone (assemblage of veins)
Outcrop
Trail
Road
Stream
Dump

***Figure 1.** Plan of the 120 m level, Detour Lake Mine. (Project 45).*

consists of a grey, fine grained dioritic matrix containing pink to buff ellipsoidal pebble-size fragments of a granodiorite to aplitic composition. The pebbles may in places have feldspar phenocrysts and are very thin. Pyrite is ubiquitous throughout the matrix and the pebbles. The composition of both matrix and pebbles is similar to individual dioritic and granodioritic intrusions in the area. The dike intrudes the mafic flows but is cut by quartz-sulphide veins. Similar intrusions have been noted in the Porcupine camp and in mine terminology have been referred to as "Goose Egg dikes".

Heterolithic Breccia

In the central area of the 120 m level, another lithological unit is mapped which has not yet been observed in the open pit. This rock is a "breccia" consisting of dark, amphibolitic matrix supporting boulder to pebble size fragments of various adjacent units (Unit B, Figure 1). The dominant type of fragments are the highly altered and veined feldspar porphyry which occurs as dikes and irregular bodies throughout the footwall and the main ore zone. Other fragments are variolitic pillowed basalts, massive basalts, and quartz-sulphide veins. The matrix and the fragments are cut by later quartz-sulphide veins.

Spatially, the breccia shows a strong association with the feldspar porphyry dikes; in the immediate vicinity of the dikes, it may contain so many larger fragments of the intrusion that it can be considered the hybrid contact of the dike rather than a breccia. Moving away from the dikes however, the size and density of the porphyry fragments decrease and the rock becomes a heterolithic breccia.

Temporally the breccia is also closely related to the emplacement of the feldspar porphyry, which cuts all the volcano-sedimentary units in the mine (Marmont 1984), and the vein-forming event. As it contains fragments of these two units, it post-dates the emplacement of the intrusion and an early stage of veining. However, since it is cut by later veins, it pre-dates the final stage of hydrothermal activity. Therefore, its formation took place during the felsic intrusive/hydrothermal activities and is not related to volcanism.

STRUCTURE

The exposures in the underground workings facilitate observation of the structural features. Within the limits of the present workings, it is apparent that the area of the footwall and the main ore zone (the southern parts of the mine) has been the focus of the most intense deformation manifested in the development of a strong mylonitic fabric and parallelism (co-linearity) of various components such as foliation, layering, lamination, schistosity, veins, and dikes. The mylonitic fabric is present in all rock types and, regardless of the protolith, the final product is a finely laminated, cryptocrystalline (result of extensive grain size reduction), highly altered rock. The appearance of this tectonic product is such that when examined in hand specimen, outside of its geological context, it may resemble a chemically precipitated "cherty" rock and therefore be misinterpreted as a stratigraphic rather than a structural marker.

As observed in the open pit (Marmont 1984), the penetrative fabric throughout the 120 m level strikes 100° to 120°E and dips vertically or steeply to the north or south. Within the limits of the surface exposures, open pit benches, and underground workings, the southern extent of the mylonitic fabric into the metasediments is not as yet defined, but northwards there is a visible decrease in the intensity of the penetrative fabric in the hanging wall mafic flows. This, however, does not necessarily reflect upon mineralization potential, as in addition to the degree of tectonic permeability necessary for fluid flow, mineralization, especially of economic value, depends on availability of fluids at the right time and suitable wall rock to allow favourable chemical reactions. The lateral extent of the deformation zone is not well defined due to lack of outcrops. Within the deformation zone, intense folding of the rocks is apparent. In many cases, ribboned quartz-carbonate-sulphide veins are asymmetrically folded with their axial plane parallel to foliation and plunging gently or horizontally. Evidence of both sinistral and dextral movements, "S" and "Z" shaped folds as well as unfolded folds, is present throughout the vein system, which indicates a complex, multistage, shearing process. In many instances, the thickened hinges of the folded veins show a remarkable sulphide concentration, a feature to be taken into account in the evaluation of the diamond drill core.

An added feature of the core of the deformation zone is the presence of densely spaced, slightly sigmoidal N-S veinlets which taper off to the north (Hanging wall) of the main ore zone. These veins represent tension gashes, a feature that develops at the final, relaxation stages of the stress field in a shear system.

PIT MAPPING

The most significant part of the mapping of the open pit was carried out in 1984 (Marmont 1984). New, lower benches exposed in 1985 are much narrower in width and therefore only expose the main ore zone and a small section into the footwall and the hanging wall. For this reason mapping of the new faces adds little to the data collected in the earlier stages of the open pit development. An 80 kg sample of the feldspar porphyry at the footwall of the main ore zone was collected from the 6216 S bench to determine the timing of the felsic intrusive event with U/Pb Zr method.

The geological features at the lower benches are fundamentally the same as described previously. The main ore zone, with local variations in strike and dip, has the same characteristics at a depth of 60 m (200 feet). At the end of the 1985 field season, the pit was developed to a depth of approximately 70 m (230 feet) on the seventh bench.

PROPERTY GEOLOGY

Parts of the area around the mine had previously been examined by Amoco Canada Petroleum Company Limited and Campbell Red Lake Mines Limited personnel. As part of a reconnaissance mapping project, some of this information was incorporated into a large-scale regional map produced by Johns (1982).

However, detailed mapping of the area with the present knowledge of the mine geology is necessary to help exploration of areas with potential economic interest in the rest of the belt. In the course of this survey, in addition to detailed mapping of known outcrops and re-logging of some of the exploratory diamond drill core, numerous new suboutcrops were uncovered, and mapped in detail. Figure 2 is a simplified map of the area accessible from the mine.

LITHOLOGIES

Mafic Metavolcanics

As in the case of the mine area, the largest volume of rocks present in the area consists of mafic, massive and pillowed basaltic flows (Figure 2). All pillowed flows are amygdaloidal and show a strong fabric which in most cases has deformed the pillow shape: however, in one location a double cusp pillow indicates the top of the mafic flows to the west. The westerly trending top may be reinforced by the presence of variolitic flows (unit Vc, Figure 2) which also occur in the western part of the area. This type of flow normally indicates the upper, later phases of mafic volcanism. The amygdules in the pillowed basalts are filled with amphiboles and minor chlorite, epidote, and feldspars.

Within the mafic flows both in and outside of the mine, occasionally there is a gradation from the fine grained basalt into a coarse grained amphibolite which in places resembles a gabbro (*see* below). However, the coarse amphibolite is either a co-eval and/or co-magmatic coarse flow with the fine grained flows or a metamorphically coarsened basalt, whereas the gabbroic intrusions cut the fine and coarse grained flows and therefore post-date mafic volcanism.

Early Mafic Intrusions

The northeastern section of the area is underlain by a large gabbroic complex (units G and D, Figure 2). This intrusion is a multiphase body and intrudes the mafic flows. The dominant phase of the complex is a medium to coarse grained gabbro; in the east this phase is the only rock type present, indicating a homogeneous, deeper part of the pluton. However, towards the west near the contact with the mafic metavolcanics, several other phases are present. Although an attempt was made to separate each of these rock types, it became apparent that individual phases are not mappable units and more likely the whole assemblage indicates differentiation of the magma in the area of the roof and marginal zones of the magma chamber. The most common rock types in the hybrid contact zone are diorite, quartz diorite, granophyric gabbro, feldspathized gabbro, feldspar porphyritic gabbro, and pegmatite. The contact of the intrusion is highly brecciated, suggesting a forceful emplacement accompanied by high pressure volatile release.

In addition to the gabbro complex, a few biotite lamprophyric dikes also constitute the early mafic plutonic event. These dikes cut the mafic metavolcanics but are in turn brecciated by the emplacement of the trondhjemitic pluton (*see* below).

Felsic Intrusions

The main phase of the felsic intrusions which cut the mafic metavolcanics and intrusive rocks consists of a fine grained trondhjemite (Marmont 1984). The emplacement of this intrusion has brecciated and in places feldspathized the mafic wall rocks. In addition to the trondhjemitic phase, there are numerous feldspar porphyry, feldspar-amphibole porphyry and aplitic dikes; in some instances the latter have miarolitic cavities. The felsic dikes cut all other rock types (including the trondhjemite) and therefore are the youngest Archean units in the area. However, since all of these felsic units show the same strong penetrative fabric as seen in the mafic metavolcanics and the gabbro complex, and in some cases have been rotated into late shears, they pre-date or are synchronous with the early stages of the late Archean deformational event.

Late Mafic Intrusions

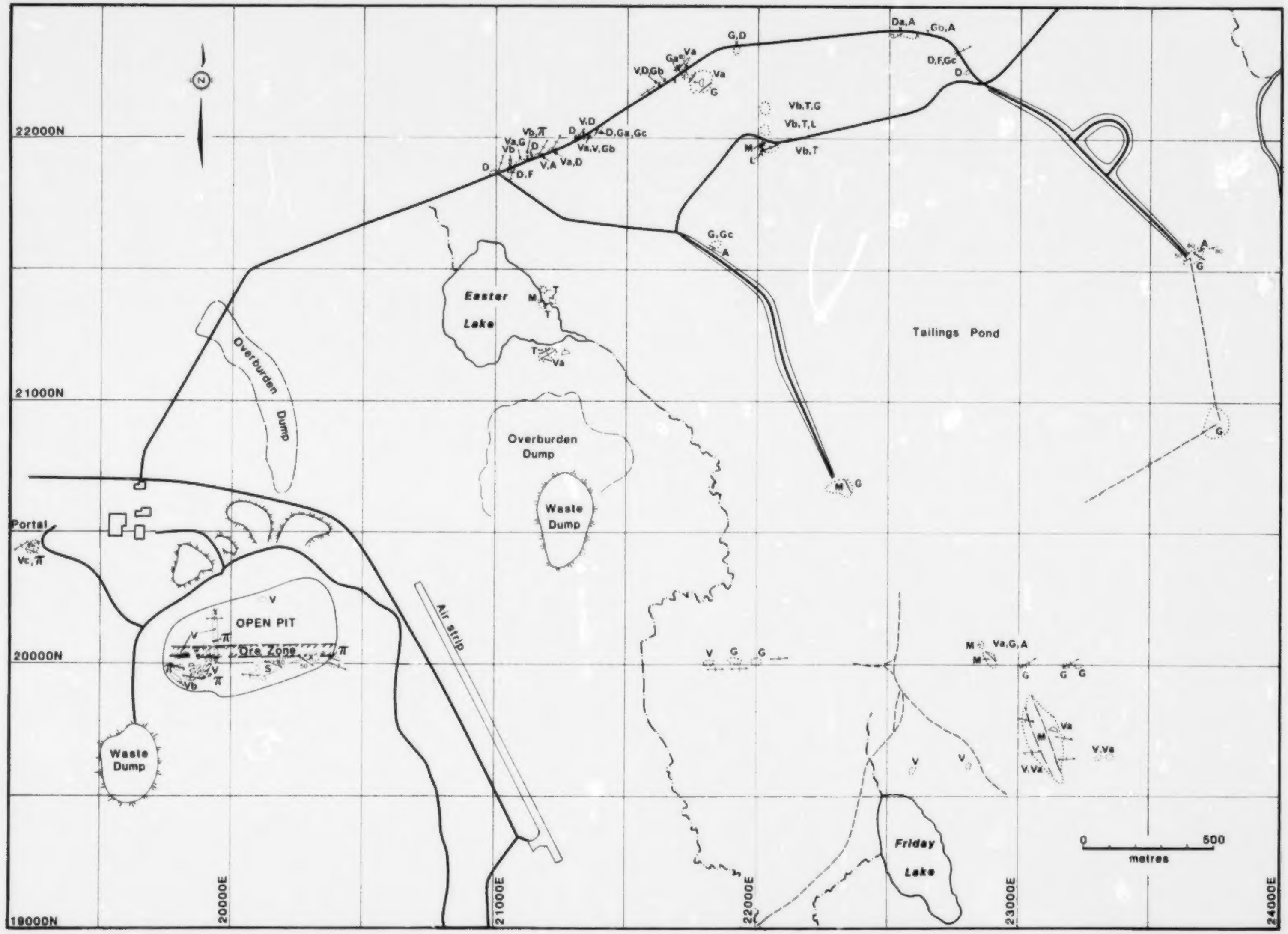
A number of late mafic dikes are present throughout the area. The most prominent intrusion of this kind is a wide (over 60 m in places) coarse to medium grained diabase dike which is exposed in the northeastern section of the area (Figure 2). This dike is massive and from the contacts towards the centre shows a distinct gradational increase in the grain size. Composition and texture, however, remain uniform throughout the dike. The overall trend of this dike is 150° to 170°E.

STRUCTURE AND METAMORPHISM

Throughout the area, a dominant penetrative cleavage manifested as flattening of the pillows, mineral alignment in the mafic and felsic intrusions, and in the more intense cases lamination of the massive mafic flows is seen; the trend of this fabric is shown in Figure 2. As discussed previously, in the mine area a general parallelism of this fabric is present at 100° to 120°E and continues to the east of the mine workings. However, northwards from the mine, the overall trend of this fabric is 40° to 60°E. From this it can be seen that the northeasterly trending fabric of the rocks to the north is rotated into an east-southeasterly trending fabric within the mine structure. At this stage it is not as yet ascertained whether the mine shear zone is the major structure in the area or whether it is a subsidiary or splay of a more extensive deformation zone.

Absence of exposures to the south and west of the area makes inference of the stratigraphy and larger scale structures difficult. To date the few top indicators (*see* section on Mafic Metavolcanics and Early Mafic Intrusion) suggest a westerly facing pile, but this information only applies on a local scale and will have to be reinforced in more locations to be applicable to the area as a whole.

In practically all the outcrops examined, a certain degree of shearing is recorded. This consists of several discrete shears of differing widths and at various stages of formation. In most cases, the sense of motion of the shears can be defined by the trend of the "S" fabric of the adjacent rocks which is rotated into the shear. Field data shows both sinistral and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Tailings Pond
Easter Lake
Friday Lake
Overburden Dump
Overburden Dump
Waste Dump
Waste Dump
OPEN PIT
Ore Zone
Air strip
Portal
Vc, π
0
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metres
G,D
Da,A
Gb,A
D,F,Gc
D
V,D,Gb
Ga
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Va
G
Vb,T,G
Vb,T,L
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Figure 2. *Simplified geology of the Detour Lake Mine and surrounding area. (Project 45).*

dextral shears are present and may constitute a conjugate set.

The degree of deformation within these shears is also variable whereby in numerous outcrops a classic mylonite with a distinct "C" fabric was documented, but in others only a weak shear "C" fabric may be seen. The presence of the shears in almost all outcrops suggests that the mapped terrain lies well within the area of the influence of a major deformation zone, the strongest manifestation of which is seen in the mine sections.

On a megascopic scale, no change in the metamorphic grade has been noted and all rocks fall in the upper greenschist-lower amphibolite facies, but microscopic examination may lead to identification of more subtle differences. Contradictory to the mine area, the rocks outside of the mineralized zone do not show a readily recognizable megascopic alteration effect, however, single quartz-carbonate sulphide veins have been seen in some locations and may contain anomalous gold values. Grab samples from these and other promising units will be analyzed and reported.

SUMMARY

From the field data gathered to date, it appears that the sequence of geological events is as follows:

1. Volcanism of tholeiitic basalts, possibly accompanied by ultramafic volcanic/intrusive components.
2. Intrusion of a large gabbroic complex and lamprophyric dikes.
3. All of these rocks were tilted showing steep to vertical dips.
4. Felsic intrusion of a sodic body and later potassic dikes.
5. A late Archean deformational event (Marmont 1984) simplified as follows:

a. Early deformation, alteration, and vein formation (quartz-epidote-carbonate set).

b. Formation of a tectonic/hydrothermal breccia.

c. Intense deformation and alteration, main vein formation (quartz-carbonate sulphide-gold set).

d. Final deformation, formation of late tension gashes and late veins (quartz-K-feldspar-carbonate set).

At present, the timing of the deposition of the clastic metasediments and the upper greenschist-lower amphibolite metamorphism is not ascertained. It should also be added that to date no felsic volcanic components have been recognized which may or may not have constituted part of the volcanic stratigraphy.

ACKNOWLEDGMENTS

The author would like to thank the geology and engineering personnel of Campbell Red Lake Mines Limited, Detour Lake project, for their continuing support of the project. In particular, thanks are due to W. Valliant (Chief Geologist), and D. Walli (underground Superintendent) who facilitated underground access. Able assistance by S. Buck of Brock University was most appreciated.

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The Northern Miner Press, January 31st, 1985.

46. The Lac des Iles Platinum Group Metals Deposit, Thunder Bay District, Ontario

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INTRODUCTION

The Lac des Iles (LDI) palladium-platinum (copper-nickel-gold) deposit in Northwestern Ontario is 90 km north-northwest of Thunder Bay (Location Map). The deposit is centred upon Latitude 49°10′N and Longitude 89°37′W, National Topographic Series map area 52 H/4 NE. The study commenced in 1985 and is concentrating upon detailed field mapping of the known mineralized zones and surrounding rocks in an area 3.5 km by 2.5 km, Figure 1. Outcrop and stripped outcrop mapping is controlled by an east-west base line cut in 1985 and by chained north-south lines at 50 m intervals. In 1985, the northern portion of the area was mapped (Figure 1) at a scale of 1:1000. The result of the mapping will be published as a Preliminary Map during the winter of 1985-86.

The LDI platinum group metal (PGM) occurrence was discovered by prospecting in 1963 (Pye 1968). While considerable exploration and assessment of mineral potential has been directed towards the property, no detailed geological map of the area containing mineralization is available. It is the objective of the study to map that part of the complex hosting mineralization and to evaluate the factors responsible for localization of the PGM, copper, nickel, and gold, with the aim of providing guides for exploration for PGM in this deposit and within similar geological environments.

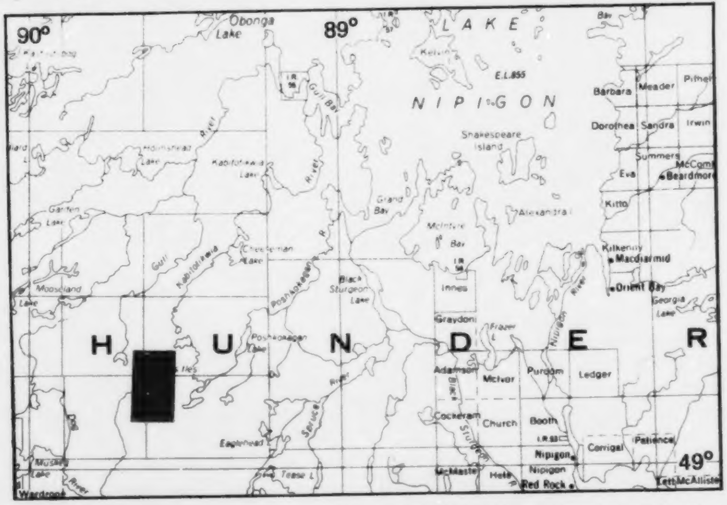
PGM COMMODITY ASPECTS

Global demand for the major PGM, platinum and palladium, increased in 1984 by 19 and 37% respectively. The minor PGM, rhodium, ruthenium, iridium, and osmium, experienced considerable pressure from both industrial and speculative sources, with prices rising during 1984 by between 300 and 700%, depending upon the element (Robson 1985). Current Rustenberg (South Africa) prices for the PGM (September, 1985) in United States of America dollars (US $) per ounce are platinum: $475; palladium: $104; rhodium: $920; ruthenium: $78; iridium: $430; osmium: $900 (M. Wilson, Industrial Sales Product Manager, Johnson Matthey Limited, Toronto, personal communication, 1985). New York Dealer Prices (NYDP) may differ considerably from Rustenberg prices. For example, in September 1985, the NYDP for platinum ranged between US $314 and $318. Current prices may be found in relevant publications, e.g. The Northern Miner Press, Metals Weekly.

Platinum supply in 1985 from the market economy countries totaled 2.5 million ounces, with South Africa providing 92.4% and Canada 6% of the total (Robson 1985). World consumption in 1985, including central economy countries, is estimated to reach 2.8 million ounces (New York Times, September 2, 1985), with an anticipated supply of 2.9 million ounces, permitting a build up in stocks of about 100 000 ounces. This contrasts with gold, where 1.9 billion ounces are in the world's inventory and consumption is only 50 million ounces per annum (New York Times, September 2, 1985).

Increased European demand for PGM to be used in automobile catalytic converters, and other considerations, have placed further pressure on PGM markets and have accelerated efforts to produce the metals from sources in North America. In addition, demand from Australia and South Korea may also increase substantially, as use of catalytic converters in these countries is being considered.

Current North American production is predominantly (90%) as a byproduct from the operations of Inco Limited and Falconbridge Limited at Sudbury, Ontario. The total Ontario production for 1984 was


90°
89°
49°
Obonga Lake
L A K E
N I P I G O N
Shakespeare Island
Grand Bay
McIntyre Bay
Alexandra I.
Gull Bay
Kabitotikwia Lake
Chief Bay
Moosehead Lake
Black Sturgeon Lake
Poshkokagan
Gull River
Kabitotikwia River
Eaglehead
Tease L.
Wardrope
Spruce River
Nipigon River
Black
H
U
N
D
E
R
Barbara
Meader
Pifher
Dorothea
Sandra
Irwin
Summers
McComb
Beardmore
Eva
Kitto
Kilkenny
Macdiarmid
Orient Bay
Georgia Lake
Innes
Graydon
Frazer
Adamson
McIvor
Purdom
Ledger
Cockeram
Church
Booth
Corrigal
Patience
Nipigon
Red Rock
McMaster
Helen
McAllister
I.R.

LOCATION MAP   Scale: 1:1 548 000 or 1 inch to 25 miles

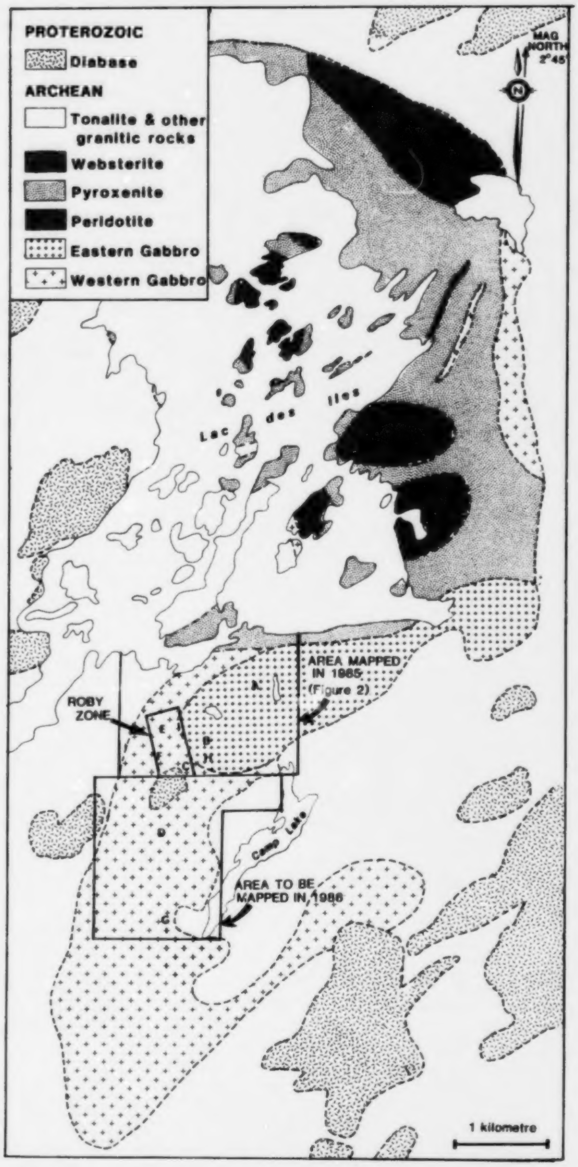


***Figure 1.** Geology of the Lac des Iles area, modified after Pye (1968) and Watkinson and Dunning (1979) showing mineralized zones referred to in the text (A to H Roby) and the area investigated in this study. (Project 46.)*

341 248 ounces, equivalent to 10 614 kg (Weatherson 1985). Inco Limited ships anode slimes from Sudbury to its PGM refinery in Acton, England. Falconbridge Limited utilizes its smelter and refinery at Kristiansand, Norway. There is no PGM refinery in Canada.

The principal reserve in North America is the Stillwater Deposit, Montana, estimated by the United States Bureau of Mines (Robson 1985) to contain 225 million ounces of PGM, (≈6 400 tonnes), at a grade between 0.4 and 0.7 ounce of PGM per ton (13 to 22 g/tonne), with a platinum to palladium ratio of 1:3.5. This contrasts with published reserves of 14 950 tonnes PGM, (527 million ounces) from the Merensky Reef, Bushveld Complex, South Africa (Cousins and Vermaak 1976); the platinum grade of the Stillwater Deposit is equal to that of the Merensky Reef, the palladium grade is seven times higher and the width of mineralization is double (Mann *et al.* 1985). In Canada there are no major potential PGM-producing deposits in pre-production stage. The Lac des Iles Deposit may represent one of Ontario's and possibly Canada's principal known PGM resources.

GEOLOGY OF THE PGM DEPOSIT AT LAC DES ILES

PREVIOUS WORK

The first detailed geological map of the Lac des Iles area was published by Pye (1965, 1968). Outcrop mapping in 1964 by Gunnex Limited was submitted to the Mining Recorder's Office in Thunder Bay for assessment purposes.

Subsequent to Pye's work, the property was optioned by Texasgulf Incorporated. Research in conjunction with and partially supported by Texasgulf Incorporated, led to the publication of two papers by workers at Carleton University. Watkinson and Dunning (1979), and Dunning *et al.* (1981) described the detailed mineralogy of the PGM-bearing phases, including various mineral combinations of Pt, Pd, Ni, Te, Bi, Sb, As, and S, the most abundant of which at Lac des Iles is Vysotskite (Pd,Ni)S. Watkinson and Dunning (1979) also described the composite nature of the gabbro portion of the LDI complex. Talkington and Watkinson (1984) described the PGM geochemistry within zones of mineralization and its bearing upon the origin of the present metal distributions.

GEOLOGY OF THE GABBRO COMPLEX

The geological map in Figure 1 is from Watkinson and Dunning (1979), modified from Pye (1968) with unpublished data from Texasgulf Incorporated. Sutcliffe and Sweeney (this volume) present a new map of the Lac des Iles complex and its regional setting. As a result of mapping in 1985 the following observations are presented; some of these support, and others provide contrary evidence against, previous statements and hypotheses; some represent new observations relevant to the mineralized rocks.

Watkinson and Dunning (1979) subdivided the gabbroic portion of the LDI complex into an eastern and western gabbro (Figure 1). They proposed that the western gabbro is the oldest intrusion and is dominantly a plagioclase cumulate with intercumulus augite. Watkinson and Dunning (1979) also recognized orthopyroxenite-plagioclase cumulate and clinopyroxene cumulate phases. The younger eastern gabbro is described as oxide-rich, layered gabbroic, and dioritic rocks, with both cumulus plagioclase and pyroxene. All known mineralized zones (A-H, Figure 1) are within the gabbroic phase of the LDI complex.

In general, the presence of two principal gabbroic phases, termed 'eastern' and 'western' by Wat-

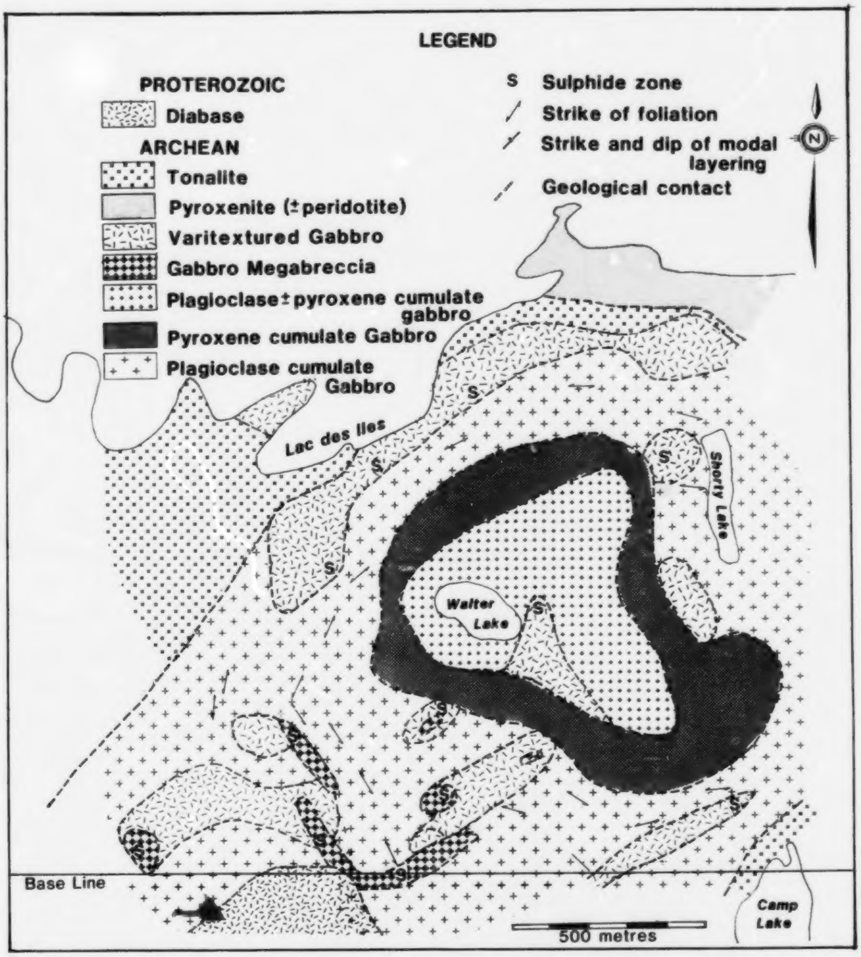

LEGEND
PROTEROZOIC
Diabase
ARCHEAN
Tonalite
Pyroxenite (± peridotite)
Varitextured Gabbro
Gabbro Megabreccia
Plagioclase ± pyroxene cumulate gabbro
Pyroxene cumulate Gabbro
Plagioclase cumulate Gabbro
S Sulphide zone
Strike of foliation
Strike and dip of modal layering
Geological contact
N
Lac des Iles
Shorty Lake
Walter Lake
S
Base Line
Camp Lake
500 metres

Figure 2. *Geology of a portion of the Lac des Iles gabbro complex. Note the spatial association between sulphide occurrences, gabbro megabreccia (GMB) and varitextured gabbro (VTG). (Project 46.)*

kinson and Dunning (1979) is confirmed, although the distribution of the 'eastern' phase may be more complex.

For the purposes of this study, rocks of the gabbroic complex were classified in the field by their colour index and cumulate phase(s). The majority of the gabbro complex mapped to date is plagioclase cumulate (Figure 2), with interstitial pyroxene and tends to be leucocratic. A phase within the centre of the mapped areas is dominated by a rind of pyroxene and pyroxene-plagioclase cumulates, commonly melanocratic, and a core of plagioclase ± pyroxene cumulate. These pyroxene-rich rocks also locally contain horizons with up to 20% magnetite, responsible for a prominent magnetic anomaly. The pyroxene cumulates correspond to part of the eastern gabbro of Watkinson and Dunning (1979) (Figure 1), with the important modification that the pyroxene cumulate melagabbro phase does not appear to be continuous to the east, but passes into plagioclase cumulate leucogabbro (Figure 2), megascopically indistinguishable from rocks classified as western gabbro by Watkinson and Dunning (1979); it appears therefore that, in the mapped area at least, the pyroxene cumulate phase is incorporated within the main body of the gabbro complex, the plagioclase cumulate leucogabbro. One surface exposure at the contact of the two phases displays clasts of plagioclase cumulate within pyroxene cumulate, suggesting that the latter intrudes the former. This would support the observation of Watkinson and Dunning (1979) that the eastern gabbro is younger than the western gabbro. Sutcliffe and Sweeney (this volume) have placed a contact of two gabbro phases to the south of the area described in this study.

Alignment of elongated plagioclase and pyroxene crystals (foliation) is common and describes an arcuate shape (Figure 2) subparallel to the proposed contact between the two gabbro phases. Modal layering, a variation in relative proportions of plagioclase and pyroxene, is less common, but in general is also subradial, about the central pyroxene cumulate (Figure 2). Pegmatitic gabbro layers, from 5 to 10 cm thick, are present rarely, parallel to modal layering. Where foliation and modal layering co-exist, they tend to be subparallel, although local discrepancies of up to 30° have been noted.

The localization of a distinct phase within the bulk of the gabbroic complex receives some support from available aeromagnetic data, reproduced in Fig-

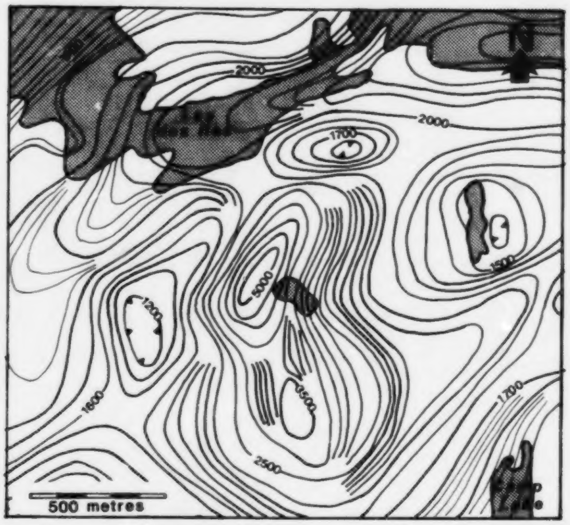


Figure 3. *Contoured aeromagnetic data for a portion of the Lac des Iles complex. Data from survey flown in 1975 submitted for assessment by Texasgulf Incorporated to the Mining Recorder, Thunder Bay. Contours suppressed in areas of high magnetic gradient. (Project 46.)*

ure 3. The magnetic highs (3500 to 5000 gammas) correspond to the magnetite-bearing cumulate pyroxene phase, flanked on all sides by magnetic depressions, corresponding to the plagioclase cumulate leucogabbro.

Pegmatitic plagioclase-pyroxene (±magnetite) gabbro with grain size up to 8 cm is found in several settings: (1) as discrete layers parallel to modal layering, as mentioned above; (2) as dikes crosscutting modal layering; and (3) as small, typically <1 m in length, vermiform segregations within otherwise uniform plagioclase cumulate leucogabbro. This rock type, termed varitextured gabbro (VTG) is also typified by small anorthosite segregations, interleaved with uniform leucogabbro, i.e. on an outcrop scale the rock exhibits local variations in both texture and composition. In the field VTG is found either at the contact of the LDI complex with country rock tonalite, or associated with zones of mineralization (*see* below).

The country rocks surrounding the LDI gabbroic phase are comprised of a medium grained, intermediate to acidic rock termed tonalite by Sutcliffe and Sweeney (this volume) and granite by Pye (1968). Whilst small scale relationships suggest that tonalite intrudes the LDI complex, as small felsic dikes are commonly present within the mafic rocks, Sutcliffe and Sweeney (this volume) have gathered evidence to suggest that the LDI basic magmas and the tonalitic magmas may have coexisted. In the map area (Figure 2), the contact between gabbro and tonalite tends to be gradational over 15 to 20 m, from gabbro to quartz gabbro to 'contaminated' tonalite to tonalite. 'Contaminated' tonalite is identical to the quartz-feldspar tonalite, but with the addition of relict ferromagnesian minerals, now intensely altered. A chaotic border phase of VTG is present at the northern contact of the gabbro (Figure 2) accompanied locally by a complex breccia of several mafic to ultramafic lithoclasts in an anorthositic gabbro matrix.

For further information, the interested reader may wish to consult the preliminary map (Macdonald, in preparation) of a portion of the LDI gabbroic complex from which Figure 2 is derived.

GEOLOGY OF THE MINERALIZED ZONES

As noted by Pye (1968), the distribution of zones of sulphide mineralization is irregular on outcrop scale. While exceptions are present locally, in general the bulk of the mineralized zones describe a partial anulus that is subparallel to foliation throughout the map area, modal layering where present, and the mapped contact between the plagioclase and pyroxene cumulate phases (Figure 2). Marked local discrepancies do exist, however; for example between the 'C' and 'H' zones (Figures 1 and 2) in the southern portion of the area, the mineralized rocks strike approximately east to northeast, whereas modal layering and foliation strike at 150° to 160°. Watkinson and Dunning (1979) suggested that a portion of the mineralized zone (the Roby Zone, Figure 1), occurred at the contact of the eastern and western gabbro. Based upon field criteria, gabbros in the immediate hanging and footwalls are megascopically identical, both being medium grained, uniform plagioclase cumulate leucogabbros.

In marked contrast to the relatively uniform gabbro exposed throughout the map area, geological relationships in mineralized zones are complex (Figure 2). Locally host rocks comprise an apparently chaotic assemblage of plagioclase cumulate, pyroxene cumulate, anorthosite, fine grained and pegmatitic gabbroic phases. The host rock is a breccia, with a matrix dominantly of pyroxene cumulate melagabbro enclosing large clasts, locally in excess of 2 m in diameter, of fine grained mafic rock and both medium and coarse grained plagioclase cumulate leucogabbro and anorthositic gabbro. The rock is termed gabbro megabreccia (GMB), a typical exposure of which is shown in Photo 1. The breccia may exhibit sharp or gradational contacts with varitextured gabbro (VTG).

It can be appreciated that without the benefit of large, recently stripped surface exposures, interpretation of core through such a rock may lead to the suggestion of interlayered plagioclase and pyroxene cumulate gabbros as opposed to a breccia matrix of pyroxene cumulate gabbro with clasts of several plagioclase cumulate gabbro types.

Clasts of gabbro phases may also be composite; e.g. a clast may consist of both gabbro and anorthosite with a distinct contact between both rock types. Clasts may or may not be foliated, but where foliation is present, it is randomly oriented. These observations suggest that the clasts in the GMB were derived from already lithified rock types and incorporated within the more pyroxene-rich gabbro liquid.

Many of these field observations and the inferences derived from them will require confirmation by

Photo 1. *Gabbro megabreccia. Note clasts of both fine and coarse grained mafic rock in a dark, melagabbroic matrix. Ballpoint pen for scale. (Project 46.)*

petrographic study and are hence subject to modification.

A summary of Pye's (1968) description of the sulphide mineralization is as follows: the occurrences consist of small quantities (<5%) of sulphides disseminated throughout the gabbro complex. Some occurrences are large, up to several hundred feet across, with apparently irregular shape and gradational boundaries with unmineralized gabbro. Sulphides in order of decreasing abundance include pyrrhotite, chalcopyrite, pentlandite, pyrite, and violarite and occur as finely disseminated grains interstitial to silicates and as rare fracture fillings in the gabbroic host rock.

Sulphides in the mineralized zones reach greatest abundance, up to 5%, in GMB showing a strong preferential localization to crosscutting gabbro pegmatites (Photo 2). Sulphide tenor in gabbro wallrock is observed to decline away from the hanging and footwalls of pegmatite dikes. Sulphides occur in three environments: (1) interstitial to silicates in pegmatitic gabbro dikes and locally in any gabbro phase in GMB or VTG; (2) in fractures within GMB or VTG; (3) within altered pyroxene crystals in GMB or VTG. Pyroxenes may be completely altered to fine grained, fibrous amphibole (uralitization), with minor chlorite and sericite, as noted by Pye (1968), Watkinson and Dunning (1979). Sutcliffe (R. Sutcliffe, Geologist, Ontario Geological Survey, personal communication, 1985), however, reports finding a fresh clinopyroxene in thin section from the 'C' zone (Figure 1).

Geological features that apparently crosscut and are younger than mineralization include:

1. Intrusion of igneo-fragmental breccia dikes, found to date only in the vicinity of the 'C' zone (Figures 1 and 2). The dikes, with a fine grained igneous matrix, contain clasts of several gabbroids mapped in the area, clasts of sulphide bearing gabbro and clasts of country rock tonalite. Petrographic and geochemical analyses of the sulphide bearing clasts will determine whether the sulphides contain PGM and whether, therefore, one may infer that these rocks are post-mineralization.
2. All rock types are cut by pyroxenite dikes, up to 20 cm in width, which in places also brecciate the gabbro complex. The pyroxenite dikes generally strike approximately north-south.
3. All rock types are also cut by felsic dikes, apparently of tonalitic affinity, as mentioned above. Locally the dikes display a granophyric texture. Quartz veins (± tourmaline) are commonly associated with the felsic dikes, at the contact of dike and gabbroic host rock of the LDI complex.
4. Several minor fracture sets cut the complex and the minor dike sets. The most prominent set strikes northeast, is locally filled by fine-grained, ferromagnesian mineral(s) (possibly chlorite) and displays sinistral offset when intersecting a traceable horizon such as an igneous contact.

SUMMARY

The principal characteristics of mineralization at Lac des Iles include:

1. the gabbroic complex contains a plagioclase cumulate leucogabbro phase intruded by a pyroxene cumulate melagabbro
2. several of the known areas of mineralization describe an arcuate zone, subparallel to, but displaced from, the contact of the two gabbro phases, within the plagioclase cumulate phase
3. mineralization is hosted predominantly by gabbro megabreccia and locally by varitextured gabbro, and is associated with development of crosscutting pegmatitic gabbro dikes
4. alteration intensity, particularly of pyroxene, by uralitization increases in zones of mineralization.

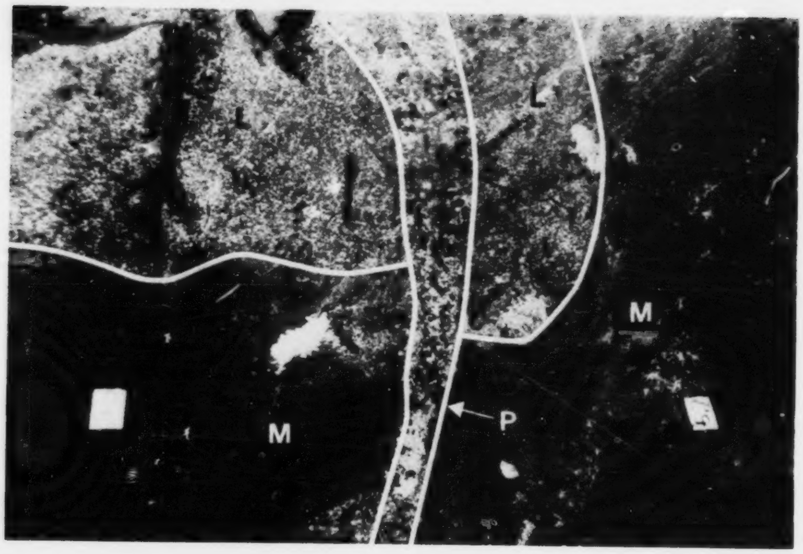


Photo 2. *Pegmatitic plagioclase-pyroxene gabbro (P) cutting plagioclase cumulate leucogabbro (L) and pyroxene cumulate melagabbro (M). Note offset of contact by pegmatite. Ballpoint pen for scale. (Project 46.)*

IMPLICATIONS OF FIELD OBSERVATIONS FOR MINERALIZATION CONTROLS

Localization of sulphide mineralization, with attendant PGE, copper, nickel, and gold, is restricted to a particular zone that is subparallel to mapped igneous contacts. It is reasonable to infer, therefore, that mineralization is controlled, at least in part, by the igneous crystallization history of the gabbro complex as suggested by Pye (1968). The characteristic complexity of rock types (GMB,VTG) in mineralized zones, when contrasted with generally uniform gabbroic rocks external to the mineralized zones, suggests that a major perturbation in the crystallization sequence of the complex accompanied mineralization, i.e. breccia development, anorthositic and pegmatitic gabbro development. The breccia contains a pyroxene-rich melagabbro matrix which may be related to the pyroxene cumulate gabbro phase (Figure 2). This hypothesis will be tested both petrographically and geochemically.

The presence of anorthosite to anorthositic gabbro may reflect either: (1) an influx, and subsequent mixing, of an anorthositic liquid into the magma chamber; or (2) segregation of an anorthositic melt from the gabbroic liquid. A difference in feldspar chemistry between the gabbroic and anorthositic rocks, detectable both by petrography and geochemical methods, would support possibility (1).

The localization of pegmatitic phases and the locally intense secondary alteration of primary magmatic silicate phases within mineralized zones may suggest elevated volatile pressures, as originally suggested by Pye (1968) and Watkinson and Dunning (1979). Pye (1968) also speculated that alteration within mineralized zones reflected a late stage or deuteric alteration superimposed upon sulphide zones that formed during the magmatic crystallization history of the complex. Watkinson and Dunning (1979) refined this concept by subdividing the sulphides into three assemblages: (1) a primary magmatic component; (2) a secondary assemblage associated with altered gabbroic rocks; and (3) a metamorphic assemblage resulting from recrystallization of secondary assemblages. Talkington and Watkinson (1984) proposed that deuteric fluids were responsible for alteration of the primary sulphide assemblage. The deuteric fluids were generated as the magma became saturated with a fluid phase during crystallization and were able to pass up through the crystal pile, mobilizing and concentrating PGM (Talkington and Watkinson 1984).

Igneo-fragmental breccia dikes may also be evidence for high volatile pressures during the magmatic event. Most interesting in this regard, is the clear spatial association, in outcrop, between sulphides and pegmatitic gabbro, suggesting that whatever process is responsible for pegmatite development may also concentrate sulphides and attendant precious metals.

Any model for genesis of the LDI mineralization must account therefore for formation of:

(1) The gabbro megabreccia
(2) Varitextured gabbro
(3) Pegmatite development
(4) Juxtaposition and superposition of (1),(2),(3).

A reasonable working hypothesis, at this stage, is that during crystallization of the plagioclase cumulate leucogabbro phase of the complex, intrusion of a second magma formed the GMB by including clasts of already lithified gabbro phases, perturbed the chemistry of the crystallizing magma, inducing local separation of anorthosite and anorthositic and pegmatitic gabbro to form the varitextured gabbro (VTG), with local extensive pegmatite development accompanied by sulphur saturation. The chemical perturbation may also be responsible for inducing elevated volatile pressures, enhancing pegmatite formation and deuteric alteration.

If the hypothesis is valid, certain diagnostic geochemical signatures may be present as noted in, for example, the Stillwater Complex. These include a quantifiable increase in the presence of hydrous silicates, a change in halogen ratios in certain species, such as apatite, and anomalously high values of rare earth elements. It is interesting to note also that at the Stillwater Complex, zones of disrupted layering and intermixing of various rock types are found below (within 100 m) the principal mineralized zone, which shows a spatial association with pegmatoidal rocks (Raedeke *et al.* 1985). At Stillwater, most researchers generally accept that PGE mineralization is associated with the mixing of magmas of two compositions (*see* Todd *et al.* 1979).

Support for this hypothesis may provide the rationale for further exploration in the zone or zones influenced by the mixing of two magmas within the LDI. Such zone(s) may prove to be spatially related to the contact(s) between different phases of the Lac des Iles gabbro complex, permitting target selection based upon surface geological mapping.

ACKNOWLEDGMENTS

I am grateful to J.P. Sheridan of Boston Bay Mines Limited for his full cooperation in permitting this project to proceed. I also wish to express my thanks to the many individuals who have aided the project at various stages: Richard Sutcliffe for much geological and logistical assistance; Michael Hine for assistance in the field throughout the summer; Henry So and Michael Reist for logistical assistance in the early stages of the project; John Scott, Ontario Ministry of Northern Affairs and Mines, Thunder Bay, for providing geophysical data; Ken Fenwick, George Patterson and all the staff of the Resident Geologist's Office, Thunder Bay for constant tolerance and good humour.

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47. Geology and Placer Related Gold Potential of the Huronian Supergroup in Part of the Northwestern Cobalt Plain

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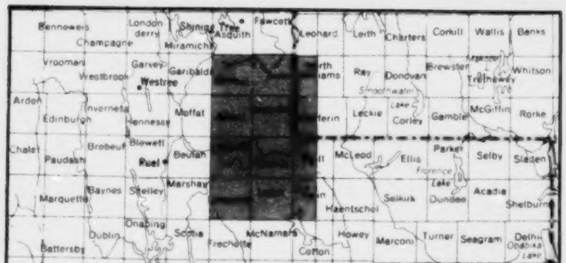
INTRODUCTION

Preliminary investigation of the geology of part of the northwestern Cobalt plain (Colvine 1981, 1982, 1983; Long *et al.* 1982; Long and Colvine 1984, 1985) indicates a potential for placer related gold occurrences in the hematitic sandstone member of the early Proterozoic Lorrain Formation. Long and Colvine (1984, 1985) indicated that local concentrations of gold (up to 1200 parts per billion (ppb)) in this member may be related to early diagenetic alteration of magnetite-ilmenite placers by ground water.

Studies in 1985 concentrated on completion of preliminary maps of Huronian strata in Sheard, Ogilvie, Amyot, Browning, Hodgetts, Unwin, Lampman, and Leask Townships; and adjacent parts of North Williams, Dufferin, Stull, and Valin Townships. Details of access, previous work, and stratigraphic framework of this poorly exposed area are given *in* Long and Colvine 1984.

NEW OBSERVATIONS

The general geology of the study area is indicated in Figure 1 (Collins 1917; Gupta 1981). Most of the study area (Figure 1) is obscured by a veneer of Pleistocene fluvial and lacustrine strata (Boissonneau 1968; Roed and Hallett 1979) with superimposed aeolian deposits. Archean granites, granodiorites, gneisses, metavolcanics, and metasediments are exposed along the western margin of the map area in Sheard, Ogilvie, Amyot, Browning, Hodgetts, and Marshay Townships; and along the eastern margin of of the area in North Williams, Dufferin, and Valin Townships. Minor inliers of Archean rocks were encountered in Unwin and Browning Townships.


Bennewers
Champagne
London derry
Shining Tree
Asquith
Fawcett
Leonard
Leith
Charters
Corkill
Wallis
Banks
Vrooman
Westbrook
Garvey
Garibaldi
Westree
Miramichi
Ray
Donovan
Brewster
Whitson
Arden
Inverness
Moffat
Trethewey
Edinburgh
Hennessy
Leckie
Corley
Gamble
McGiffin
Rorke
Chalet
Brobeuf
Blewett
Beulah
McLeod
Ellis
Parker
Selby
Sladen
Paudash
Rue
Marshay
Smoothwater
Florence Lake
Marquette
Baynes
Shelley
Selkirk
Dundee
Acadia
Haentschel
Shelburne
Onaping
Scadding
Dublin
Frechette
McNamara
Howey
Marconi
Turner
Seagram
Delhi
Obabika Lake
Battersby
Cotton
Muldrew
Onaping
Dunbar
Sweeny
Beaumont
Grigg
Stobie
De Morest
Clery
Athlone
Fairbairn
Beresford
47°
Dennie
Morse
Antrim
Emo
Lake
Rhodes
Roberts
Creelman
Fraleck
Telfer
Mc Connell
Sheppard
Afton
Bothe
Gilbert
Strasak
Ulster
Munster
Leinster
Tyrone
Kitchener
Hutton
Parkin
Aylmer
McCarthy
Mackelcan
Macbeth
Benny
Craig
Hess
Harty
Foy
Bowell
Wisner
Norman
Rathbun
Kelly
McNish
Moncrieff
Capreol
Solski
Tofflemire
Hart
Cartier
Levack
Morgan
Hanmer
Maclennan
Davis
Janes
Vermilion
Capreol
Scadding
Acheson
Ermatinger
Windy
Levack
Dowling
Balfour
Lumsden
Blezard
Chelmsford
Garson
Falconbridge
Street
Loughrin
Henry
Venturi
Cascaden
Rayside
Garson
Vernon
Totten
Trill
Fairbank
Creighton
Snider
McKim
SUDBURY
Dryden
Awrey
Hagar
Ratter
Bigwood
Creighton
Neelon
Coniston
Dunlop
Porter
Hyman
Drury
Denison
Graham
Lively
Waters
Copper Cliff
Cleland
Hawley
Appleby
Dunnet
Agnew
Nairn
Broder
Baldwin
Louise
Worthington
INDIAN RES
81°
Secord
Burwash
Hendrie
Jennings
Casimir

LOCATION MAP

Scale : 1 : 1 548 000
or 1 inch to 25 miles

Strata of the Gowganda Formation lie unconformably on Archean rocks in the southern, southwestern, and northeastern parts of the map area. They include intact and disrupt framework conglomerates; laminated mudstones; and massive, plane bedded and laminated, coarse to very fine sandstone. While part of this sequence may have been deposited in a subglacial setting (Long and Leslie 1982) most appears to have been deposited in deepwater environment with little direct glacial influence. Lithologically, most of the Gowganda Formation in the map area can be considered as part of the Coleman (lower) member. Siltstones and mudstones correlative with the Firstbrook (upper member of the Gowganda Formation), may be present south of Barnet Lake in western Leask Township.

The Lorrain Formation rests unconformably to disconformably on rocks of the Gowganda Formation in Lampman, Leask, Valin, Hodgetts, Stull, Dufferin, and North Williams Townships; and on Archean basement in Unwin, Browning, North Williams, Dufferin, and Valin Townships. Differential preservation of the Gowganda Formation may be related to a period of early deformation associated with fault activity on north-northeast – south-southwest sets in earliest Lorrain times.

The lower part of the Lorrain Formation in the map area consists of green to white feldspathic to subfeldspathic sandstones with minor quartz pebble conglomerate horizons (equivalent to members b and c of Card *et al.* 1973) of braided fluvial origin. In Ogilvie, North Williams, and Leask Townships conglomeratic horizons within the basal 200 m of the formation contain minor igneous clasts (granite, syenite, and rhyolite) similar to those present in conglomerates near the base of the formation in Milner and Nichol Townships, south of Gowganda.

The middle Lorrain Formation consists of pebbly subfeldspathic sandstone and quartz arenite of braided fluvial origin with local quartz-chert pebble conglomerate horizons (unit d of Card *et al.* 1973). Some of these exhibit local hematite staining and contain distinct heavy mineral laminae now represented by hematite. This member is well developed in North Williams, Dufferin, Ogilvie, Browning, and Valin Townships, and constitutes the favoured target for placer related gold exploration.

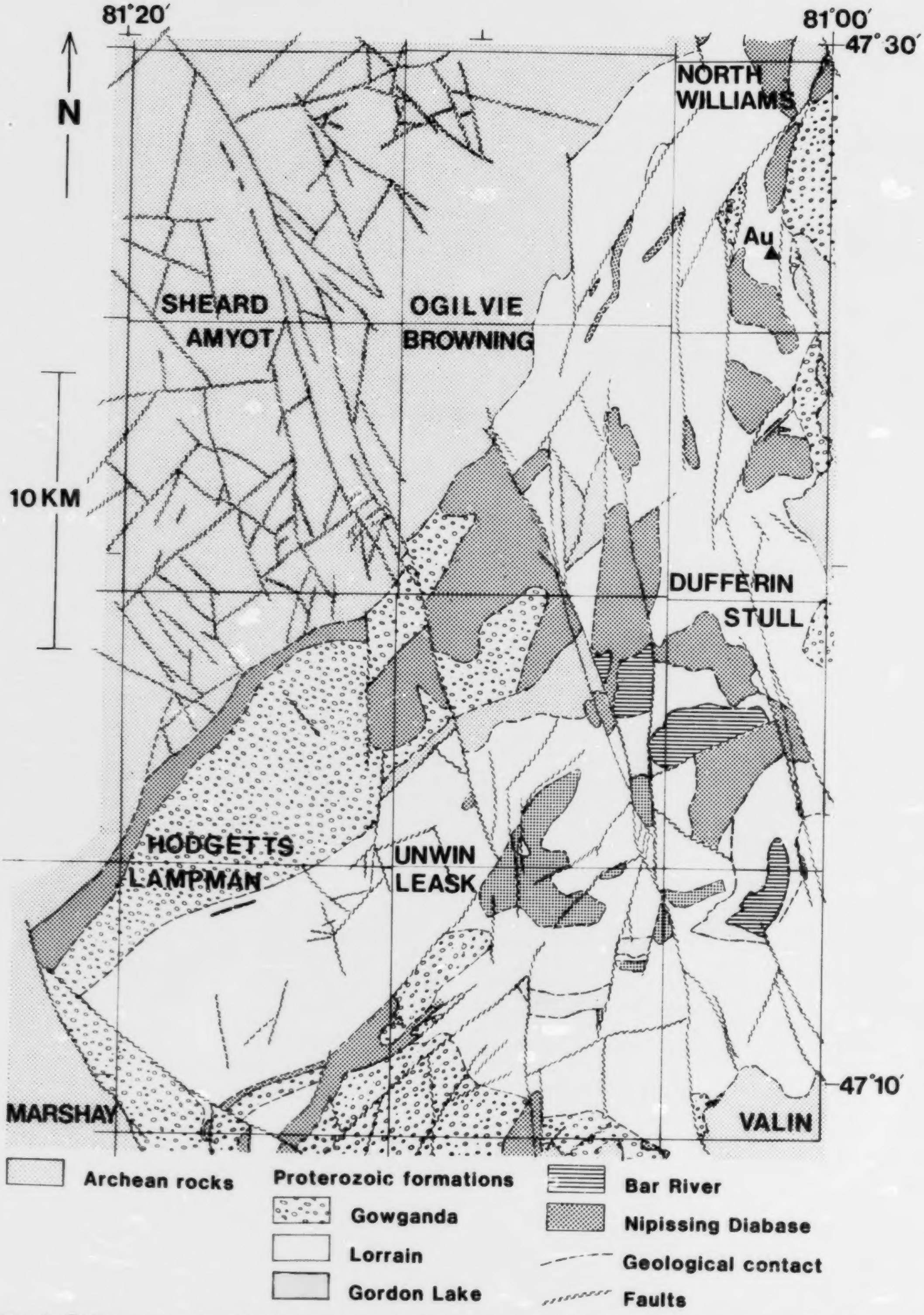

81°20′
81°00′
47°30′
47°10′
N
10 KM
NORTH WILLIAMS
Au
SHEARD AMYOT
OGILVIE BROWNING
DUFFERIN STULL
HODGETTS LAMPMAN
UNWIN LEASK
MARSHAY
VALIN
Archean rocks
Proterozoic formations
Gowganda
Lorrain
Gordon Lake
Bar River
Nipissing Diabase
Geological contact
Faults

Figure 1. *Geology of part of the western margin of the Cobalt Plain. See Location Map; and Roed and Hallett (1979) for geographic features. (Project 47.)*

The upper Lorrain Formation contains medium- to very coarse-grained feldspathic to subfeldspathic sandstones (with minor quartz pebble conglomerate) which gives way to medium-grained quartz arenites in the upper part of the sequence (units e and f of Card *et al.* 1973). While the lower of these two units is of braided fluvial origin, the origin of the quartz arenite member is enigmatic.

The upper few metres of the Lorrain Formation are exposed on a small island in Welcome Lake and along the hydro access road in Valin Township. On Welcome Lake they are subfeldspathic and contain a local coarsening upwards sequence in which up to 4 m of ripple and planar cross stratified medium sandstones, with alternating opposed (herringbone) paleoflow indicators, are overlain by 0.65 to 0.8 m of large scale planar cross stratified coarse sandstone with minor mudstone intraclasts. These are succeeded by 0.75 to 2.7 m of wavy and through cross stratified coarse sandstones with distinctive recessive weathering concretions, and a further 5 m of massive or large scale planar cross stratified medium sandstone. This coarsening upwards sequence can be interpreted as a tidal influenced beach facies. Bimodal opposed cross stratification in the lowest unit indicates deposition in a flood dominated subtidal to intertidal setting. Larger scale units above this may represent intertidal channel fills, or attached shoreface bars, overlain by intertidal and supratidal facies. Recessive weathering nodules probably represent gypsum or anhydrite nodules (F.W. Chandler, Geologist, Geological Survey of Canada, Ottawa, personal communication, 1985) produced in a coastal sabkha setting. Massive to planar cross stratified units above this may represent coastal dunes.

Rocks of the Gordon Lake Formation are present in Unwin, Stull, Leask, and Valin Townships. While the lower part of the formation contains a distinctive red sandstone member in the vicinity of Welcome Lake; most of the formation consists of laminated argillite with thin beds of very fine quartz sandstone and minor intraformational conglomerates. Although some mudstone units exhibit syneresis cracks, no direct evidence for exposure can be found within the formation. Chandler (1985) suggests that nodules of chert, quartz, and carbonate in the formation represent diagenetic replacement of entrolithic anhydrite nodules. The primary anhydrite (or gypsum) may have been precipitated diagenetically from percolating groundwaters derived from the upper Lorrain Formation. The Gordon Lake Formation is best explained as deposits of a tidal and storm influenced shelf (Chandler 1985). Diffuse bimodally opposed paleocurrent distributions recorded from the middle part of the formation have similar polarity to distributions in the tidally influenced upper member of the Lorrain Formation.

The Bar River Formation is preserved in the core of the Welcome Lake syncline in Valin Township, or ridge crests south of the Wanapitei River in Stull Township and in isolated exposures north of the river in Unwin Township. It consists of more than 125 m of white, predominantly massive and flat, laminated, fine and very fine quartz sandstones which conformably overlie strata of the Gordon Lake Formation. Paleocurrent distributions support Chandler's (1985) hypothesis that this formation accumulated in a tidally influenced inner shelf setting.

ECONOMIC GEOLOGY

Analysis of the gold content of 283 samples by the Ontario Geological Survey Geoscience Laboratories, using atomic absorption techniques, confirms our hypothesis (Long and Colvine 1984) that the middle or hematitic member of the Lorrain Formation, is the favoured host for placer related gold concentrations in this area. The maximum observed value (for *in situ* material) of 1060 ppb gold (≈0.034 ounce gold per ton) was from a non-pebbly trough cross stratified unit from the middle member of the Lorrain Formation in North Williams Township (Figure 1). The auriferous bed did not contain visible heavy mineral bands and had only local hematite staining. Other sandstones from the immediate area contained from 3 to 22 ppb gold. Associated small pebble conglomerates contained from 4 to 150 ppb gold. The 1200 ppb gold assay obtained by Colvine (1983) was from a drift boulder of very well sorted small pebble conglomerate in a pit 1 km southwest of the location indicated in Figure 1.

Distribution of gold values is shown in Table 1. Five of twelve samples from the Gowganda Formation contained gold in detectable amounts (2-7 ppb). Fifteen of seventy-three samples from the lower Lorrain Formation contained 2 to 10 ppb gold. Hematitic pebble conglomerates (with minor igneous clasts), with minor heavy mineral bands in the lower member are not a good exploration target. Thirty of seventy-one samples from the middle member contained detectable gold values (2-1060 ppb). High values are concentrated in the northern part of the map area, hence future exploration should be concentrated in North Williams Township and adjacent townships. Twenty-two of seventy samples from the upper Lorrain Formation contained from 2 to 7 ppb gold. Seven of twenty-six samples from the Gordon Lake Formation contained 2 to 6 ppb gold. Only one of nine samples from the Bar River Formation contained detectable gold values (3 ppb).

Minor concentrations of gold, up to 60 ppb were recorded from carbonatized Archean intermediate metavolcanic rocks (pillow lavas) from central Unwin Township (Figure 1). Minor silver-cobalt mineralization is present within and in proximity to sills of Nipissing Diabase in the map area.

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TABLE 1. GOLD VALUES (PPB) FOR HURONIAN STRATA IN THE NORTHWEST COBALT PLAIN. (PROJECT 47)
ND = NOT DETECTED.

Township/	Bar	Gordon		Lorrain FM		
FM	River	Lake	upper	middle	lower	Gowganda
Leonard	-	-	-	-	-	-
				NDx2	NDx3	
Ogilvie	-	-	3	2	2/2/3/4	-
			NDx5	NDx7	NDx5	
North	-	-	-	4/4/3/4/22/6	-	-
Williams				1060/13/150/30		
				NDx1		
Browning	-	-	2/2/4	10/13	8/4	-
			NDx9	NDx4	NDx4	
Dufferin	-	-	-	6/6/2/3/11/3	-	-
			NDx4	NDx11	NDx4	
Hodgetts	-	-	-	-	3	4/7/4
				NDx1	NDx1	NDx2
Unwin	-	-	-	-	-	-
			NDx1			
Stull	3	2	3/4	2/6	-	-
	NDx4	NDx4	NDx6		NDx1	
Lampman	-	-	-	2	-	2
				NDx7	NDx20	NDx2
Leask	-	6	4	5/4/2/13	10	-
		NDx1	NDx6	NDx9	NDx19	NDx3
Valin	-	2/2/4	7/2/4/6/7	4/13/5	5/3	4
		6/2	4/5/4/2/7			
			4/2/3/3			
	NDx4	NDx12	NDx17	NDx1	NDx4	
Cotton	-	-	-	-	5/2/3/3/2	-

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48. Granite and Anorthosite as Ceramic Raw Materials

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INTRODUCTION

A survey of granite and anorthosite as potential ceramic raw materials was undertaken in the 1984 field season (Vos 1984). Preliminary analytical results of rock samples have indicated that some granites in the Westport map area are of sufficient interest to test larger samples. Field work in 1985 consisted of collecting such samples.

LOCATION

The granites sampled in this project form part of the white granite indicated in bright blue on Map 1182A, Geology Westport, Ontario (Wynne-Edwards 1967). Particularly the granites at Long Lake (Latitude 44°31'30"N; Longitude 76°24'W) and Charleston Lake (Latitude 44°34'20"N; Longitude 76°01'W) are here considered.

GEOLOGY

White granitic rocks in the Westport map area occur in association with crystalline limestone. Their white colour is ascribed by Wynne-Edwards (1967, p.39) to the reduction of red ferric iron in feldspars by carbon dioxide from the limestones. In this group, the larger bodies are distinguished as pegmatite (map unit 12) and granite and syenite (map unit 12a). The pegmatite differs only in grain size from the granites and syenites. Mineralogically these granitic rocks consist mainly of quartz and a white feldspar, generally microcline and oligoclase intergrown as string mesoperthite or patch perthite (*op. cit.*, p.39). Accessory minerals reflect the composition of the adjacent host rock and may include graphite, pyroxene, phlogopite, apatite, and/or pyrite.

Preliminary analysis of granite in this area produced the results shown in Tables 1 and 2.

DISCUSSION

The preliminary analysis of granite in the Westport map area shows several features of interest. The medium to coarse grained granite has a high potassium content (5.57% to 8.98% K_2O by weight). The generally low iron content may be due largely to an average 5% iron-rich accessory minerals (mica, amphibole). The possibility of separating a commercial feldspar fraction from this rock was considered adequate reason to pursue further analyses.

An average 20% to 30% by weight of quartz will be produced in the process of feldspar separation. Economic operation requires that this material meets commercial specifications or lends itself to beneficiation for use in advanced ceramics.

METHODOLOGY

Evaluation of granite as a potential source of ceramic raw material requires a determination of the quality of individual components. It must be established whether the bulk rock lends itself to economic separation of quartz, feldspar, and mica of sufficient purity and adequate grain size to serve the manufacturing industry. The product to waste ratio is an important factor in the overall evaluation.

In order to study these aspects of the granite, samples of approximately 30 kg each had to be provided. The samples were taken from blocks of granite broken by sledge hammer and freed from weathered material at surface or along fractures as completely as possible. The samples included both granite and pegmatite.

Analytical work will be undertaken at Queen's University, Kingston, under supervision of staff in Mining Engineering.

A report on all aspects of this project will follow completion of the analytical work.

ACKNOWLEDGMENTS

Vigorous assistance in the field was provided by Henry So, Geological Technician, Mineral Deposits Section, and analytical work was carried out by staff of the Geoscience Laboratories, Ontario Geological Survey, Toronto.

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TABLE 1. ANALYSES (WEIGHT %) OF GRANITE NEAR LONG LAKE (2-7) AND CHARLESTON LAKE (11), WESTPORT MAP AREA. (PROJECT 48.)

	2	3	4	5	6	7	11
SiO_2	71.50	69.90	72.80	70.10	69.30	71.30	69.90
TiO_2	0.05	0.18	0.15	0.17	0.15	0.21	0.06
Al_2O_3	14.90	15.00	14.20	13.40	13.60	14.70	15.30
Fe_2O_3	0.07	0.22	0.15	0.36	0.29	0.22	0.29
FeO	0.27	0.39	0.17	1.33	0.77	0.68	0.52
MnO	0.01	0.01	0.01	0.01	0.01	0.0	0.01
MgO	0.27	0.39	0.17	1.33	0.77	0.68	0.52
CaO	2.67	3.67	1.66	3.32	2.58	0.51	1.00
Na_2O	3.24	2.39	2.10	2.33	2.04	1.63	2.40
K_2O	5.57	5.57	6.98	7.21	8.09	8.98	8.72
P_2O_5	0.01	0.01	0.01	0.02	0.06	0.04	0.0
CO_2	0.85	0.81	0.51	0.84	1.28	0.25	0.62
S	0.02	0.29	0.14	0.12	0.17	0.17	0.0
H_2O^+	0.33	0.36	0.17	0.18	0.31	0.53	1.82
H_2O^-	0.08	0.12	0.15	0.13	0.17	0.19	0.16
TOTAL	102.24	102.59	100.86	102.84	101.40	99.92	101.80
LOI	1.00	0.70	0.80	0.90	1.80	0.80	1.10
SP.GR.	2.58	2.58	2.58	2.60	2.60	2.58	2.58
TOTAL Fe: (as FeO)	0.33	0.59	0.30	1.65	1.03	0.88	0.78
TOTAL Fe: (as Fe_2O_3)	0.37	0.65	0.34	1.84	1.15	0.98	0.87

TABLE 2. MINERALOGICAL COMPOSITION OF GRANITE NEAR LONG LAKE (2-7) AND CHARLESTON LAKE (11) IN WEIGHT % CALCULATED FROM BULK ELEMENT CHEMISTRY AND DETERMINATION BY X-RAY ANALYSIS*. (PROJECT 48.)

Sample	Quartz	Plagioclase	K-Feldspar	Rest	Mica	Chlorite	Amphibole	Others
2	27	38	33	2	-	-	-	-
3	31	31	31	7	P	-	P	-
4	31	25	41	3	P	-	-	-
5	25	25	43	7	P	-	P	Dolomite
6	24	25	48	3	-	-	-	Dolomite
7	26	16	53	5	P	P	P	Calcite
11	21	25	50	4	-	P	-	-

*P = Present in minor amount (includes minerals named in column "Others").

49. Clays and Shales in Southern Ontario as Potential Ceramic Resources

P. Martini and J.F.P. Kwong

Martini and Associates, Guelph, Ontario with Introduction by J.S. Springer, Geologist, Ontario Geological Survey, Toronto.

INTRODUCTION

Several lines of argument suggest that Ontario should be searching for ceramic raw materials from which durable, temperature resistant goods can be manufactured. Two arguments hinge on evident market capacity which exists today and the third upon the need for evolution in part of the manufacturing sector so as to prevent losses of skills, jobs and capital investment.

Firstly, in 1984, finished clay products to the value of over $188 million were imported into Canada. 26.5 percent of this comprised ceramic tile of various kinds such as interior and exterior floor tile, quarry tile and decorative wall tile. The value for Ontario imports for this same year was over $26 million (Prud'homme 1985). Other estimates by federal agencies show that in 1983 Canadian demand for ceramic floor and wall tile represented a market of $90-100 million.

These agencies assess Canadian production as about 15 million square feet per annum for the years 1972-1981. In contrast a private sector evaluation of demand (Windsor Ceramic Tile Canada Limited 1985) foresees an immediate need of 130 million square feet per annum. In the United States a much larger volume is traded. The 1982 market is estimated at 650 million square feet valued at $600 million (Fitzgerald 1982) and the activities of the Tile Council of America ensure that these figures are increasing.

Thus even with new production capacity, reported by federal estimates to reach 73 million square feet in 1985, there are deficits, which will be satisfied by imports from Europe, at provincial, national and North American levels. This may mean that given proper resources there is opportunity to sell residential construction tile that is manufactured in Ontario.

Trends in markets for roofing tile, a second area of opportunity, can be gauged by the success of Marley Roof Tiles Limited which set out in 1982 to introduce concrete roof tiles to the residential construction industry. Since then its sales have doubled every year and will soon reach 3.5 million tiles a year without saturating the market (Bernard Curtis, Plant Manager, Marley Roof Tiles Limited, personal communication, 1985). This suggests that similar products in clay would be well received provided they meet requirements of frost resistance, durability, colour and low weight.

A third argument which points to the need for seeking better resources in Ontario is the declining state of the ceramic drain pipe industry. The number of producers who make earthenware field drains has shrunk steadily in the past twenty years. An analysis of this manufacturing sector (B. Feenstra, Resident Geologist, Ontario Ministry of Natural Resources, London, personal communication, 1983) showed that competition from plastic piping, which is lighter and easier to install, has reduced the use of clay tile severely. The few drain tile manufacturers left are under considerable pressure to diversify into product lines for which there is a better demand (see below). Tested resources with higher refractory qualities would enable such manufacturers to evolve into more competitive market areas without disrupting business, to utilize their existing skills in heavy clay production, retain a trained workforce, and make use of existing plants as a foundation for new ventures.

SEARCH AREA AND RESOURCE QUALITY

As a first approach the search for quality ceramic resources in Ontario was limited geographically because principal markets lie in the United States or in Southern Ontario. Moreover the greatest concentrations of both historically known resources and of heavy clay manufacturers lie south and west of Toronto. Together these reasons defined the optimum search area.

The desired quality of resources was defined by taking specifications of materials needed to produce frost-resistant roofing tile. The requirements include firing temperatures above 1100°C, low moisture absorption in the finished tile, good compressive strength and impact resistance, all of which are a measure of the mineralogy and chemical composition of the starter materials. By taking roofing tile as the yard-stick, resources tested to this level will automatically be suitable for products such as flue liners, sewer pipe and flat tile ware, for which conditions of use are less exacting.

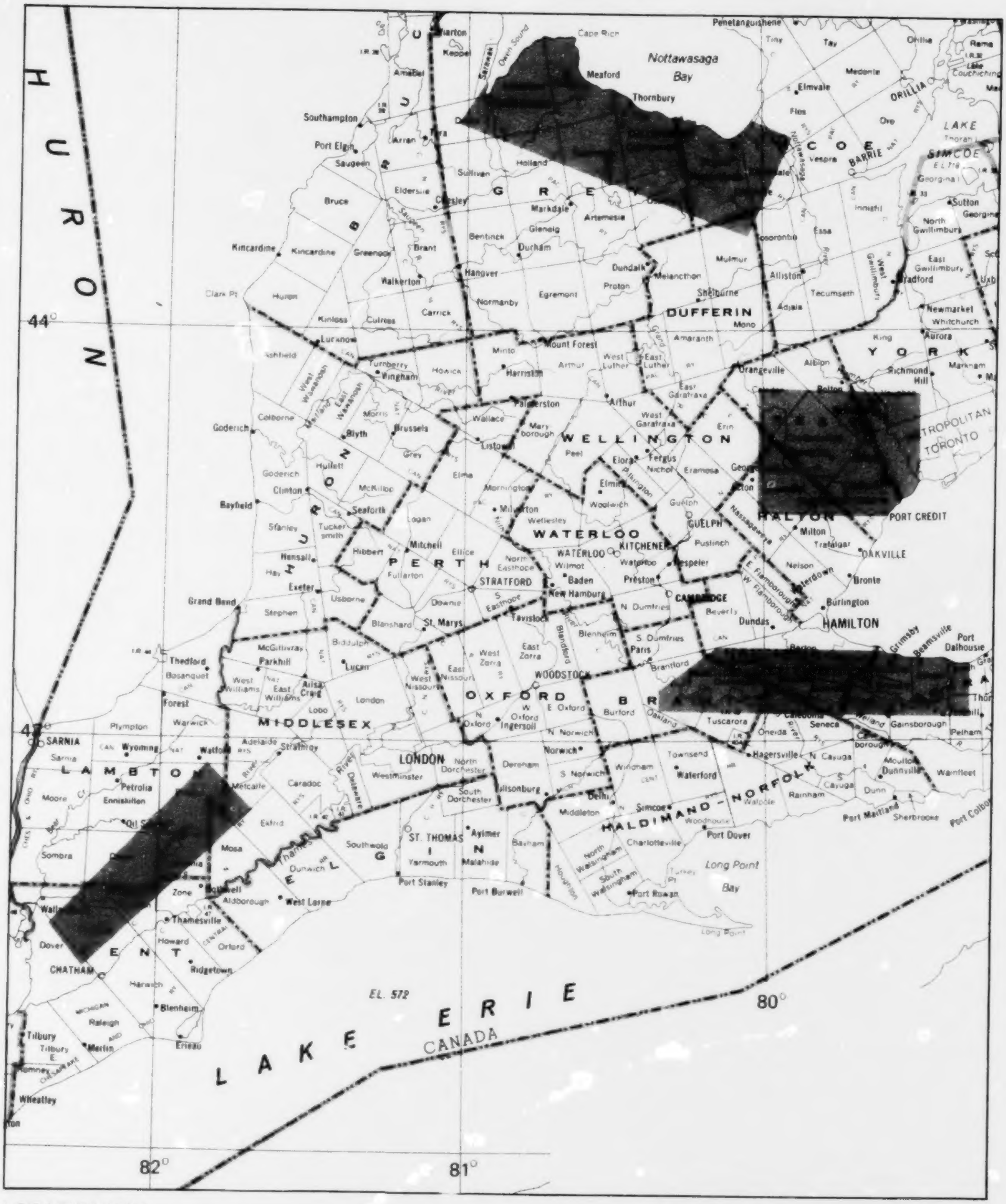
FIELD EXAMINATION

During July 1985 a number of sites were selected on the basis of prior work, in collaboration with staff of the Ontario Ministry of Northern Affairs and Mines and the Ontario Ministry of Natural Resources. Field studies comprised two aspects:

(a) Sedimentological examination and mapping to identify depositional environments. This will permit a good estimate of vertical and lateral extent of deposits on a site specific basis and will enable a clearer assessment of tonnages available.

(b) Collection of representative samples for standard mineralogical, chemical and ceramic testing.

For sedimentological studies spot samples were taken during the detailed field documentation of the outcrops and cores. These samples will also enable checks to be made if anomalous results are obtained in the ceramic testing. For ceramic studies several channel samples, each 30 kg, were collected to ensure proper representation of various parts of the deposits. Table 1 shows the geologic units sampled. Maps and detailed site descriptions are in preparation as a result of this field study.


HURON
LAKE ERIE
Nottawasaga Bay
LAKE SIMCOE
Long Point Bay
METROPOLITAN TORONTO
CANADA
GREY
BRUCE
SIMCOE
DUFFERIN
YORK
WELLINGTON
HALTON
WATERLOO
PERTH
HURON
OXFORD
MIDDLESEX
LAMBTON
KENT
ELGIN
BRANT
HALDIMAND-NORFOLK
Cape Rich
Meaford
Thornbury
Penetanguishene
Orillia
Barrie
Owen Sound
Southampton
Port Elgin
Kincardine
Walkerton
Hanover
Durham
Markdale
Dundalk
Shelburne
Alliston
Newmarket
Aurora
Richmond Hill
Orangeville
Mount Forest
Harriston
Palmerston
Listowel
Wingham
Lucknow
Goderich
Clinton
Seaforth
Bayfield
Exeter
Grand Bend
Mitchell
Stratford
St. Marys
Elmira
Fergus
Elora
Guelph
Kitchener
Waterloo
Preston
Hespeler
Cambridge
Galt
Paris
Brantford
Woodstock
Ingersoll
Tillsonburg
Simcoe
Delhi
Port Dover
Port Rowan
Port Burwell
Aylmer
St. Thomas
Port Stanley
London
Strathroy
Thedford
Forest
Sarnia
Petrolia
Wyoming
Watford
Oil Springs
Thamesville
Chatham
Ridgetown
Blenheim
Dresden
Wallaceburg
Tilbury
Merlin
Erieau
Wheatley
Dover
Milton
Oakville
Port Credit
Bronte
Burlington
Hamilton
Dundas
Waterdown
Grimsby
Beamsville
Port Dalhousie
Caledonia
Hagersville
Cayuga
Dunnville
Port Maitland
Waterford
Wainfleet
Port Colborne
Pelham
West Lorne
Rodney
Dutton
44°
43°
82°
81°
80°
EL. 572

LOCATION MAP

Scale: 1:1 548 000 or 1 inch to 25 miles

TABLE 1. GEOLOGICAL UNITS SAMPLED FOR CERAMICS STUDY. (PROJECT 49.)

Age	Geological Unit	Locality	Sample Identification
Recent	Alluvial clay	S.W. Ontario	ALC
Pleistocene	Lacustrine clay	Dresden	DRS
Pleistocene	Lacustrine clay	Brantford	PLB
Devonian	Kettle Point	Kettle Point	KTL
Devonian	Kettle Point	Alvinston	KTL 2
Devonian	Arkona	Hungry Hollow Top	AKHt
Devonian	Arkona	Hungry Hollow Core	AKHb
Devonian	Arkona	Coultis	AC
Silurian	Cabot Head	Payette Hill	CHP
Silurian	Cabot Head	Owen Sound	CHO
Silurian	Cabot Head	Inglis Falls	CHF
Silurian	Cabot Head	Griersville Rock	CHG
Ordovician	Queenston	Burnstein	OQB
Ordovician	Queenston	Vineland	OQV
Ordovician	Queenston	Merritt St.	OQT
Ordovician	Queenston	Grimsby	OQY
Ordovician	Queenston	Milton	OQM
Ordovician	Queenston	Streetsville	OQS
Ordovician	Queenston	Huttonsville	HV1
Ordovician	Queenston	Georgetown	OQW1
Ordovician	Queenston	Limehouse	OQL
Ordovician	Queenston	Cheltenham	OQH
Ordovician	Queenston	Creemore	OQE
Ordovician	Queenston	Griersville Cr.	QUG
Ordovician	Georgian Bay	Creemore	GBE
Ordovician	Georgian Bay	Winkler Parkway	—
Ordovician	Georgian Bay	Meaford	GBM
Ordovician	Georgian Bay	Christie Beach	—
Ordovician	Blue Mountain	Camperdown	BMM
Ordovician	Blue Mountain	Camperdown	CAM
Ordovician	Blue Mountain	Christie Beach	BMC
Additives:	Albert Shales	New York, U.S.A.	...
	Ohio Shale	Ohio, U.S.A.	...
	Ohio Underclay	Ohio, U.S.A.	...
	Pennsylvania	Penn., U.S.A.	...

LABORATORY ANALYSES

A set of 16 samples representing the raw materials with best anticipated characteristics was selected from the total number collected. They were chosen to show a spread as wide as reasonable in age and geographic placement, given that the quality must be as high as possible. This set was subjected to mineralogical and chemical analysis, and to testing of ceramic properties both before and after firing.

A further set of 10 composite samples was made from mixtures of the above materials. The combinations of samples and the mix proportions were selected by estimating from already known properties. The aim is to create blends with a longer firing range, such that the product does not melt and become glassy over a very short temperature range (short-firing ranges demand unpractically careful temperature control in the kilns), and to lower the absorption to less than 6% such that frost damage by spalling will be negligible.

MATERIAL PREPARATION

The material for ceramic testing was ground before extrusion to pass a 200 micrometre sieve. To meet the specification of the contract which requires firing of tile wares, a special die orifice was designed and machined to fit the high pressure extruder available at the CANMET Laboratory in Ottawa where testing was conducted. The materials will then have been tested under conditions which closely approximate modern production methods.

TESTS CONDUCTED

To date the laboratory work completed includes chemical analysis by XRF for resources in untested deposits, differential thermal analysis, and thermal dilatometric analysis. In the ceramic testing program, 36 samples of shales, clays and their mixtures have been extruded in tile form and fired to 6 finishing temperatures (915°C, 991°C, 1050°C, 1086°C, 1101°C, and 1117°C). Seven samples were treated also by "semi-dry press" forming process, and the resultant wares were fired to the 6 finishing temperatures. Ceramic properties determined include: plasticity, slow and rapid drying characteristics, mixing water content, scumming and efflorescence characteristics, drying and firing shrinkages, absorption (cold and boiling and cold/boiling ratios), dry unit weight of fired products, colour, warpage and cracking, green and fired modulus of rupture and Mohs hardness. Scumming problems experienced with some materials, such as shales from the Arkona and Georgian Bay Formations, were successfully overcome by addition of small amounts of barium carbonate. Laboratory tests in progress include semi-quantitative XRD analysis of clay and non-clay minerals, and particle size analyses of selected samples.

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50. Colour Clues to Concentration of Iron Pigments and Gold at the Paleozoic—Precambrian Unconformity

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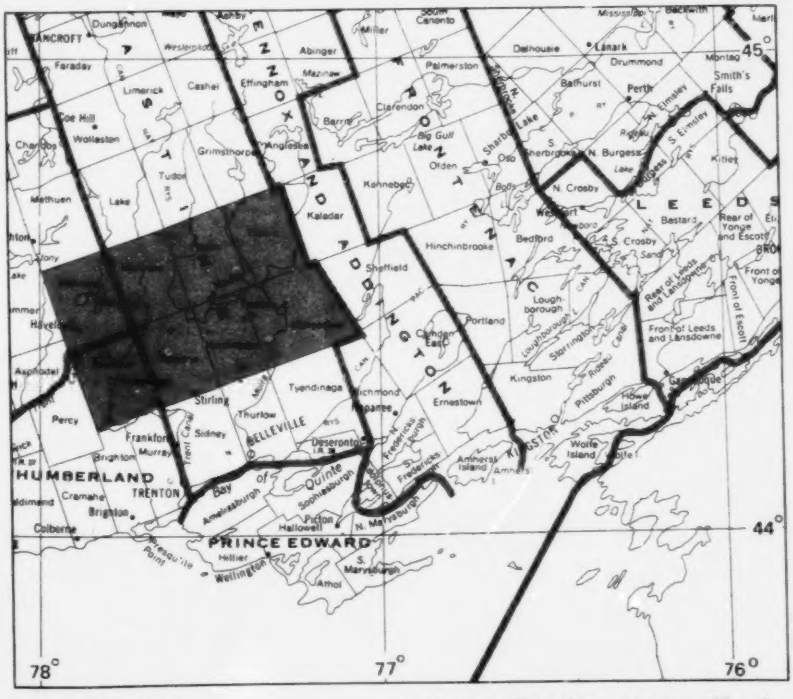
INTRODUCTION

Early records of mineral exploration in Hastings County, Southeastern Ontario, describe deposits of earthy or partly crystalline hematite filling depressions or veins near surface (Vennor 1870). As more work was done, it became apparent that these deposits were in part gossans developed on top of skarn iron ores found in the Precambrian rocks (Rose 1958). Oxidation extends up to 20 m below surface (Hewitt 1968) on some of the iron skarns (for example, the Wallbridge Hematite Mine) forming substantial bodies of oxide mineralization. These bodies were sufficient in size to be used in some cases as the earliest iron ores of the region, for example, the Coe Mine (Hewitt 1968). Some deposits, such as the Wallbridge Hematite Mine were used as sources of pigments for the early paint mixtures and some such as the Richardson Mine in Madoc Township (Vennor 1870) and the Cordova Mine in Belmont Township (Blue 1894) were found to contain spectacular coarse gold values in ferruginous earths above the sulphide ores. So the "red earths" of this area are indicators for deposits of soft iron ore which is locally of a quantity and grade suitable for pigment, and in more restricted instances, they indicate supergene enrichments of gold.

The geographic area underlain by Grenvillian rocks has particular constraints for the development of mineral deposits. Because much of the area is close to large urban centres and the land base is privately held, there are strong dictates to the manner in which development is undertaken. This means that both social and economic factors have to be taken into account.

In that light, small operations, mining oxide ores of gold, perhaps for their collector and mineralogical value, may be viable. "Collector's" items can be ten to a hundred times the commodity value of the mineral. There is considerable economic spin-off from a mine operated as a tourism-oriented venture where the revenue is generated by trying to find the commodity, that is panning for gold, not by finding and selling the commodity.

Supplying high-quality iron-oxide as pigments is also realistic. Natural iron oxides (hematite, limonite, geothite) are used as red, yellow, and brown colourants in concrete products such as roofing tile, patio blocks, terrazzo composites, and tinted concrete (Koxholt 1985). As pigments, natural iron oxides also find application in plastics, industrial coatings, and paints and cosmetics. In these uses, they are chosen above artificial oxides if volume and colour are consistent and the unit price is competitive. Furthermore, hematite in a micaceous habit is a valuable functional filler used in abrasion resistant rustproof coatings for metal work. Hematite cannot be artificially made cheaply. Materials from sources in the Grenville Province could well be competitive in all these uses if made available to the plastics, coatings,


Dungannon
BANCROFT
Faraday
Limerick
Cashel
Effingham
Abinger
Mazinaw
Miller
Palmerston
Dalhousie
Lanark
Drummond
Bathurst
Perth
Montag
Smith's Falls
45°
Coe Hill
Wollaston
Chandos
Methuen
Lake
Tudor
Grimsthorpe
Anglesea
Barrie
Clarendon
Kennebec
Kaladar
Olden
Oso
Sharbot Lake
S. Sherbrooke
N. Burgess
N. Crosby
Westport
LEEDS
Bastard
Kitley
Rear of Yonge and Escott
Sheffield
Hinchinbrooke
Bedford
S. Crosby
Front of Yonge
Front of Escott
Rear of Leeds and Lansdowne
Front of Leeds and Lansdowne
Loughborough
Portland
Storrington
Camden East
Havelock
Asphodel
Percy
Stirling
Thurlow
Sidney
Tyendinaga
Richmond
Napanee
Ernestown
Kingston
Pittsburgh
Howe Island
Gananoque
BELLEVILLE
Deseronto
Frankford
Murray
Brighton
NORTHUMBERLAND
Cramahe
Brighton
TRENTON
Bay of Quinte
Ameliasburgh
Sophiasburgh
Fredericksburgh
Amherst Island
KINGSTON
Wolfe Island
Colborne
PRINCE EDWARD
Hillier
Wellington
Hallowell
Picton
N. Marysburgh
S. Marysburgh
Athol
Presqu'ile Point
44°
78°
77°
76°

LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

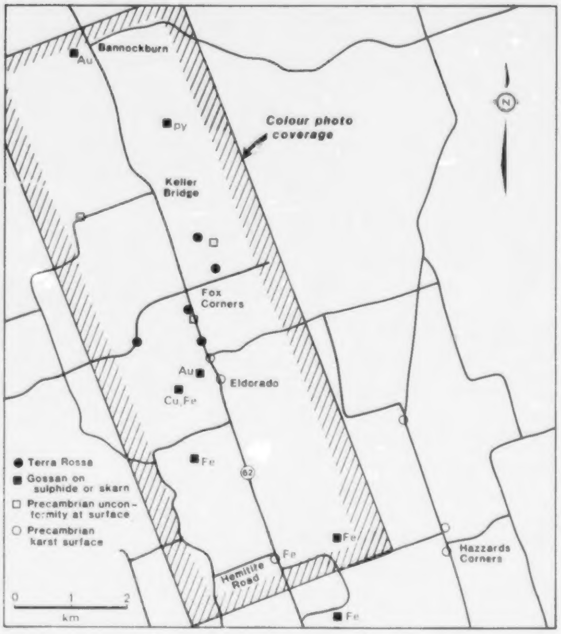


Figure 1. *Part of Madoc Township showing supergene enrichments of Au, Fe, Cu, erosional features (karst plane of unconformity) and depositional features (terra rossa) related to the Precambrian unconformity. (Project 50.)*

and concrete products industries which are clustered in the greater Toronto-Hamilton area.

THE STUDY AREA

Part of Madoc Township was selected as a study area (Figure 1) to examine the distribution of red ochres and supergene gold enrichment. The distribution of these materials lies within a zone of oxidation which outcrops at surface and is reported sporadically in literature from the 1850s up to the present time, but it has not been systematically recognized and mapped.

Ground checks soon made it apparent that the zone is bounded by an upper plane which dips gently south, and that the more detailed hilly configuration of the surface is too small to be mapped at the contour interval shown on base maps having a 1:50 000 scale. The zone can be traced on the ground, even where outcrop does not occur, by local reddening in the glacial drift or the soils.

STRATIGRAPHIC POSITION OF THE OXIDATION ZONE

The Precambrian is unconformably overlain by unmetamorphosed Paleozoic rocks. The main Paleozoic transgression, well marked by carbonate deposition, is dated on fossil evidence as being Middle Ordovician. Below this transgressive unit, however, is a mixed unit which is regionally very variable. The common feature of this mixed unit is that it lies between the plane of unconformity and the first bedded carbonates. The mixed unit, however, is a composite which reflects both deposition at different times and widely varying environments of deposition within the same time intervals.

In Peterborough and Hastings Counties, rocks of this stratigraphic position (the mixed unit) vary from being quartzose grits and calc-arenites to being laminated shales. There is commonly a pebbly basal conglomerate incorporating jaspery red quartzite or discrete grains of hematized magnetite. The grits and shales are strongly coloured red, purplish, green, or mottled combinations of these colours.

Where the Paleozoic can be seen to rest upon the Precambrian, it is apparent that beneath the unconformity there is pervasive reddening of rocks of all compositions. Even in granitic rocks, fracture planes are coated with hematite, but the effect is even more marked in mafic varieties where iron oxides are converted to hematite.

Oxidation and reddening are signs of a pre-Paleozoic event, this can be shown by the inclusion of reddened Precambrian fragments in green or grey Paleozoic rocks, but the redness has also affected the colour of later sediments deposited upon the unconformity. Thus the colouration of the basal Paleozoic in this area is a reflection of the redness in the basement rocks.

The same colour is picked up by glacial tills which, very locally, are reddened (2 to 300 m m thick, E.V. Sado, Geologist, Ontario Geological Survey, personal communication, 1985). The youngest horizons affected by the Precambrian colouration are the post-glacial soil profiles developed discordantly across both Precambrian and Paleozoic bedrock; the Eldorado and Deloro soil types (Gillespie *et al.* 1962) are commonly reddish. The distribution of both glacial and soil colouration is very closely tied to the distribution of the underlying red rocks. There has been very little glacial smearing of the colour down ice or blurring of the distribution by soil development. Consequently, the distribution of the Precambrian oxidation where it reaches today's land surface, can be read reasonably accurately from the 1 inch to 2 mile soil maps, for those areas where soil is developed.

COLOUR AIR PHOTOGRAPHY

To see whether the surface could be followed on the basis of colour as an indicator of mineral concentrations and to provide a topographic base for working, a small strip of colour air photographs was flown in April 1983 north-south along Highway 62, north of Highway 7 (Figure 1) and the area, which runs along Highway 62, from the Hematite Road to Bannockburn, was chosen to cover a number of iron skarns and gold occurrences with known oxidation zones (Hewitt 1968). The scale of the photo coverage is approximately 1:10 000.

Stereoscopic examination of the air photographs shows that the red colouration which marks the Precambrian unconformity is visible from the air. In April, when the flight was made, the fields were bare, and the remains of the winter's snow was apparent in north-facing hollows. Tilled fields showed a distinct colouration, and where the Precambrian bedrock emerges from the cover materials, a halo of reddening is seen to increase towards the emerging bedrock. Slight variations in colour tone can be seen. Near known iron deposits (for example, Wallbridge Hematite Mine), the colour is a blue-toned red, and elsewhere it is yellower. Colour is developed on the carbonates as well as immediately adjacent to iron skarns, so that there has been either redistribution of secondary iron, or iron-rich residues are developing from the carbonates. Later field examination had made it probable that these are terra-rossa deposits developed as residual ferruginous materials by dissolution of the carbonate.

Stereoscopic examination also revealed a geomorphology on the carbonates which appears to be karstic. Conical hills with sloping sides equally steep on all sides, different from asymmetrical glacial features, appear to be erosional remnants of a mature karst landscape. Solution patterns have been controlled by lithological variations in the folded marbles and a number of fracture directions. This well-developed karst in the Precambrian surface can be discerned even where, on the present surface, a thin cover of basal Paleozoic is present. It seems that where glaciation has removed the more compact slabby Paleozoic limestones, the coarse gritty basal Paleozoic has been the plane of greatest weakness. This has left a cover of red or green grit and shales thinly masking the unconformity.

THERMAL IMAGERY

In order to test other methods of remotely sensing the unconformity, a thermal image of Madoc Township observed from LANDSAT 4, dated October 24th 1982 (10:18 standard time) was examined by R. Mussokowski of the Ontario Centre for Remote Sensing. Areas of differential heating or cooling were examined and those due to south facing slopes, high relief, wetness, forest vegetation, or other evident relationships were discounted. It was hypothesized that the remaining areas of high thermal values might indicate dryness or slight topographic elevation beneath a soil cover, both of which might indicate shallow soils and the presence of a bedrock "high".

This was checked on the ground and of the 40 to 50 hot spots shown, about 75% were indeed Precambrian bedrock having a 2 to 3 m thick cover of basal Paleozoic or glacial material. The remainder were bouldery till or well-drained esker patches. This means that, for this area, the configuration of the basement can be read through a thin cover even though on the ground, the presence of a bedrock 'high' would be unknown. For large parts of the strip covered by colour photographs, the present land surface is, within a depth 2 to 3 m, the excavated surface of Precambrian erosion.

THE AGE OF THE KARST

Solution features are also developed on the flat-lying Paleozoic carbonates, but their scale is much smaller than on Precambrian marbles. Nothing like the karst landscape is seen on Paleozoic limestones. Unless one assumes firstly that the karst development is post-Ordovician, and secondly that it has developed at very different rates on the two different types of carbonate, it must mean that there was an episode of karst formation which is pre-Paleozoic, and which reached a stage of considerable maturity before inundation by the Middle Ordovician seas.

FIELD CHECKS

In order to verify the air photograph interpretations, field checks were made. Ground truthing shows that the Precambrian surface of the carbonates does locally slope appreciably away from the peaks of conical hills. The dip of this surface is difficult to record precisely because the basal Paleozoic is early weathered and covers the unconformity. However, conclusive evidence of Precambrian karst is shown on marbles at Hazzards Corners. Here, small 1 cm deep solution pits are developed in vertically banded calcite marbles. These solution hollows are filled with indurated basal Paleozoic grit. Below the unconformity, the characteristic iron staining is present. In dolomitic marbles farther north, 10 cm deep swallow holes are filled with reddened grit and chips of dolomite host, and the largest example shows white calcarenite "sandstone" discordantly infilling a 50 cm wide swallow hole.

This evidence directly implies that at some time before the Paleozoic transgression, the Precambrian was a land surface undergoing subaerial dissolution. The occurrence of indurated terra rossa deposits, of strongly oxidized iron ores, and of coarse free gold then becomes self-evident as the results of subaerial weathering, on an old land surface, upon which there has been supergene enrichment.

In addition, the distribution of other mineral associations at this horizon then becomes significant. Deposits of vermiculite such as those in Cavendish Township (Guillet 1962) and near Stanleyville, the Norden and Olympus properties (Guillet 1962; Mckinnon *et al.*, this volume) are commonly deeply weathered and lie close beneath the Paleozoic unconformity. By analogy with deposits in the United States where vermiculite formation can be shown to be a weathering episode superimposed upon an earlier metamorphic event (Boettcher 1966; Libby 1975), it is suggested that Precambrian weathering may have influenced Ontario vermiculite deposits.

Furthermore, Sangster and Bourne (1982) and Carter (1984) have drawn attention to the association of the post-Ordovician veins, which contain fluorite, strontium, and barium minerals, and lead-zinc mineralization with the unconformity. Statistically, there is a higher than normal correlation of these veins with the plane of unconformity, and they are most frequently hosted by the Precambrian rocks. The control here seems to have been porosity in brittle, sometimes dolomitic rocks which channeled mineralizing solutions into the porous rocks above the unconformity where they ponded beneath the first Paleozoic carbonates. The depth of Precambrian karstification is still unknown. Substantial bedded deposits may exist in the Precambrian marbles beneath the unconformity, comparable to Pine Point and Bleiberg which contain a comparable mineral suite.

SUMMARY

Soft hematite ores for pigment in plastics, concrete products, and industrial coatings could become viable as small operations in the Grenville.

Supergene accumulations of gold worked for their collector's appeal, or developed for tourism-oriented endeavours may also be economic.

These mineral accumulations both occur below Paleozoic rocks, at the Precambrian unconformity; this unconformity is the key to discovering other mineral accumulations. Rocks below the erosion plane are strongly oxidized, and there has been supergene enrichment to produce typical "oxide" ores of gold and iron. Vermiculite and the post-Ordovician veins containing fluorite, lead-zinc, barium, and strontium minerals are also spatially close to the plane of unconformity. Mineralization of Pine Point type could also exist.

In the field and on colour photographs the unconformity can be traced as it is clearly marked by reddening below the unconformity, in the immediate overlying Paleozoic, in glacial deposits, and in recent soils.

"Hot spots" in thermal imagery can point to basement "high" points when more obvious correlations have been examined and discounted.

The unconformity was at one time a land surface, and subaerial dissolution in Precambrian times produced both dissolution features and a mature karst landscape. The patterns of dissolution are controlled by lithological banding intersected by a number of fault directions.

A later karst event of lesser magnitude has influenced the Paleozoic rocks at some time between the Ordovician and Recent time.

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51. Natural Flake Graphite—Ontario Possibilities

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INTRODUCTION

Natural flake graphite has unique physical properties which make it an irreplaceable commodity in the iron and steel-making industry. The principal use of graphite is as a high-quality refractory lining material for furnaces; wherever it is used, alone or with MgO and Al_2O_3, in liner areas it is subjected to severe corrosion and turbulence.

In Japan, the United States, and the European Economic Community (EEC), the principal theatres of steel-making practice, the long term pressure for energy-saving, process rationalization and cost reduction (Hayashi 1983), and towards steels of consistent chemistry and high purity, that is "clean" steel (Van Dreser and Neely 1983), has driven steel makers towards common choices in refractory materials. Graphite is amongst the few natural substances suitable for liner use under the exacting service conditions of the basic oxygen or electric arc furnaces. For this reason, graphite is becoming a vital commodity in the economy of steel-making countries like Canada and the United States.

Moreover, there is a distinct trend (Hayashi 1983; Hayashi and Nishio 1983; Van Dreser and Neely 1983) towards greater use of flake graphite which has thus been at a premium since 1979 (Pettifer 1980). The trend has been disguised in the early 1980s by a world recession and falling steel production, but can be expected to surface again as the steel market recovers. In addition, production difficulties at established sources like Sri Lanka and Malagasy (Pettifer 1980) and increasing demand from the Japanese industry, have meant that all types of crystalline graphite are in short supply.

Against this background, the absence of domestic production in the U.S.A. is remarkable. Consumption in the United States is projected to increase 2.8% per annum to the year 2000 (Taylor 1985). Also, for the three steel-making sectors of the world, U.S.A., EEC, and Japan, 5% to 30% growth is forecast for the next few years (Pettifer 1980). Canada is also a net importer of graphite flake (Shank 1981). In 1979, Canada was totally dependent on imports, but since 1980 (Pettifer 1980), a single supplier in Quebec has begun partly to service domestic needs.

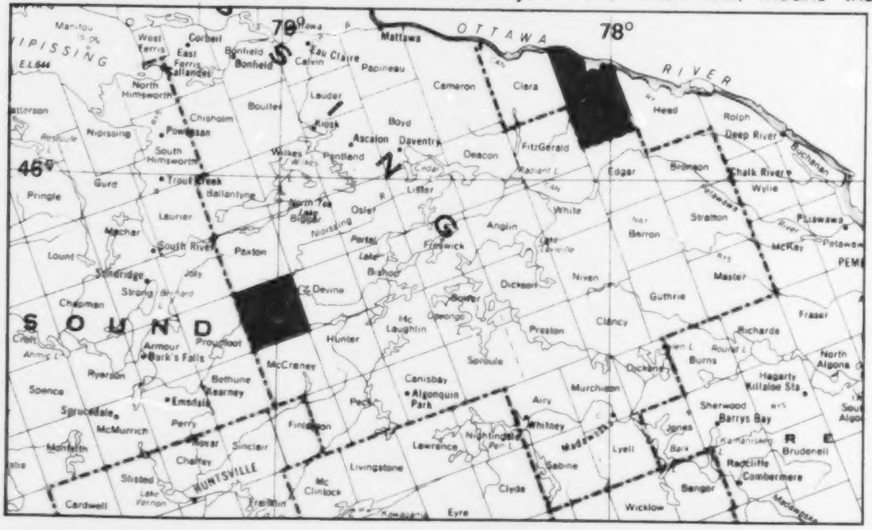
The above circumstances mean that Ontario could enjoy a two-fold economic advantage by developing supplies of quality flake graphite, particularly if the source were close to the heavy industries along the Great Lakes and the St. Lawrence Seaway. Firstly, Ontario would ensure a domestic supply vital for the Canadian steel industry, and secondly Ontario would provide a high-value lightweight export commodity readily saleable to specialist users across the world.

SPECIFICATIONS FOR NATURAL GRAPHITE IN REFRACTORY USES

Metallurgical uses compose 70% of the natural graphite market, and here, particle size and size range are of great importance.

Once a concentrate of more than 85% carbon can be achieved, the flake characteristics become decisive factors in judging graphite quality. Larger flakes may be either discrete natural flakes of this size, or such flakes may be material prepared by milling segregations of more coarsely crystalline graphite. Markets are well supplied with graphite of flake size below 0.074 mm (200 mesh US), but flake in the size range 0.297 mm to 0.15 mm (50 to 100 mesh US) is in good demand (Pettifer 1980; D. (Ted) Harley, President, Vesuvius Crucible Company, personal communication, 1983).

Characteristics for evaluation are flake shape and toughness, both of which affect resistance to thermal shock; oxidation resistance (burning rate), which determines the life of the crucible; and bulk density, which, when low, means that only small


79°
78°
46°
OTTAWA RIVER
NIPISSING
SOUND
Mattawa
Corbeil
East Ferris
Callander
Bonfield
Calvin
Eau Claire
Papineau
Cameron
Clara
Head
Rolph
Deep River
Chalk River
Wylie
Buchanan
North Himsworth
Chisholm
Powassan
South Himsworth
Trout Creek
Boulter
Lauder
Kiosk
Ascalon
Boyd
Daventry
Wilkes
Pentland
Deacon
FitzGerald
Edgar
Brennan
Nipissing
Gurd
Pringle
Laurier
Machar
South River
Ballantyne
North Tea Lake
Bishop
Osler
Lister
White
Anglin
Barron
Stratton
Petawawa
McKay
Paxton
Joly
Strong
Sundridge
Chapman
Lount
Devine
Niven
Dickens
Guthrie
Master
Fraser
Armour
Burk's Falls
Proudfoot
Hunter
McLaughlin
Preston
Clancy
Richards
Burns
North Algona
Ryerson
Spence
Bethune
Kearney
McCraney
Canisbay
Algonquin Park
Sproule
Murchison
Hagarty
Killaloe Sta.
Sprucedale
Emsdale
McMurrich
Perry
Peck
Airy
Whitney
Sherwood
Barrys Bay
Monteith
Novar
Sinclair
Finlayson
Nightingale
Lawrence
Jones
Lyell
Brudenell
Chaffey
Stisted
Huntsville
Livingstone
Sabine
Radcliffe
Combermere
Cardwell
Franklin
McClintock
Eyre
Clyde
Bangor
Wicklow
Madawaska
RENFREW

LOCATION MAP

Scale: 1:1 548 000 or 1 inch to 25 miles

amounts of bonding clay must be added and therefore shrinkage on drying is minimized (Tron 1964).

For U.S. manufacturers (Tron 1964), Number 1 flake must assay >88% C; Number 2 flake grades 82% to 88% C. In 1964, the following flake size distribution was quoted (Tron 1964):

8% >0.850 mm (B55 No. 18); 75% >0.500 mm (B55 No. 30); and 100% >0.300 mm (B55 No. 52).

Requirements of crucible makers in 1983 are quoted by the Vesuvius Crucible Company (D. Harley, President, Vesuvius Crucible Company, personal communication, 1983).

A sample with 70% to 75% carbon should show flake size distributions as follows: ideally 25% >US mesh 50 (0.297 mm); but acceptably as 25% >US 50 (0.297 mm); 50% >US 100 (0.150 mm); 15% >US 150 (0.074 mm) and 10% <US 150 (0.074 mm).

Where this size distribution is achieved, orebodies with >4% graphite may be viable, although bulk grades in the 5% to 10 % carbon range are preferable. Other specifications require an ash content of <15%, <5% volatiles, <0.5% iron and sulphur, <0.2% K_2O. Japanese refractory graphite also requires <25% weight loss on firing at 1000°C for two hours (Hayashi and Nishio 1983). Intergrowths of other flaky minerals (biotite, muscovite, sericite, vermiculite) must be carefully separated. The flakes should be thin relative to flake diameter (a high aspect ratio) and a concentrate should pack normal to the flake layering, with a volume decrease of up to 60%.

In Harley's opinion, a geographically well-placed orebody with 10% carbon in the ore, which retained 50% graphite on 100 mesh, would today be considered a rich deposit. In contrast, a 4% carbon orebody which retained 50% on 100 mesh would be marginal.

CHARACTERISTICS OF SOME SUCCESSFUL FLAKE GRAPHITE DEPOSITS

In general, flake graphite deposits are mined by open pitting. Those deposits which are profitable as underground operations have rich seams up to 2 m thick in which secondary concentration of graphite with the growth of fibrous or platy intergrowths of massive crystalline carbon has increased grades to 25% or more. Underground working and subsequent crushing make operations more costly. In addition, a well-cemented host rock which requires much crushing will cause a quality loss by size reduction of the graphite flakes. In these settings, extra cost and losses on grinding are offset by the naturally high grades.

By contrast, open pit operations can win graphite from deposits of overall lower grade, particularly where the host rock has been partly disaggregated by pervasive weathering and alteration. Secondary residual concentrations, commonly preserving the original flake size, can be easily upgraded by jigging, light crushing, and washing. Flake graphite from Brazil (Pettifer 1980; Konta 1979) and the Malagasy Republic (Pettifer 1980) are screened from metamorphic schists that have been kaolinized by tropical weathering. Malagasy ore grades 3% to 10% graphite, but large tonnages are available from strata 3 to 30 m thick and several kilometres in strike length.

ONTARIO GRAPHITE DEPOSITS OF GRENVILLIAN AGE

Grenville graphite deposits have been documented by many authors (Spence 1920; Hewitt 1965; Storey and Vos 1981; Papertzian 1982; Papertzian and Kingston 1982; Dillon and Barron 1982; Springer 1982; Villard and Garland 1984, 1985); even the better vein deposits, such as Black Donald and Beidelmann-Lyell show low amounts of large flake, even though their gross carbon content is high. Storey and Vos (1981) quoted 15% flake with an average grade of 65% carbon for the Black Donald Mine, historically the largest of these deposits.

For refractories needs, the disseminated flake reported in Ryerson, Butt, Maria, and Laurier Townships seem more promising (Villard and Garland 1984). These authors describe zones <30 m to >300 m in apparent width extending for a distance over 3 km along strike. In Butt Township, graphite grades of 2% to 4% by weight with local zones of up to 10% occur; in Ryerson Township, average grades of 2% to 4% by weight across widths of 50 to 100 m are reported along strike lengths of several kilometres (Villard and Garland 1984, 1985).

The distinctive advantage of these stratiform units is the large size and good crystallinity of the flake, much of which is >4 mm across. Nevertheless, the rather low overall grades of carbon present make it critical to liberate as much flake as possible without losing flake size.

BACTERIAL LEACHING FOR FLAKE LIBERATION

A possible solution to this is suggested by the weathering behaviour of these horizons which typically develop a friable texture and yellow coatings of jarosite (Springer 1982) due partly to oxidation of sulphides commonly present with the graphite. The rock is mechanically disaggregated by alteration. In recent years, recovery processes which enhance sulphide breakdown by bacterial action have been developed for copper, uranium, and precious metals (Davies 1984). Pyrite contamination is removed from coal in the same way (Kargi and Robinson 1982).

As it is possible that bacterial action may enhance flake liberation, 2 to 10 kg samples have been shipped to the CANMET Extractive Metallurgy Laboratory in Ottawa for testing, where H.W. Parsons of the Coal Research Branch will establish which bacterial strains most effectively break down sulphides. Samples were obtained in collaboration with Regional staff of the Ministry of Northern Affairs and Mines (M. Garland, Huntsville Office) and came from Butt and Maria Townships. Field mapping and a report by M. Garland, Resource Geologist, Ministry of Northern Affairs and Mines, Huntsville, is in preparation.

If this method works, it may be possible to prepare high-grade concentrates in which the average flake size is well over 1 mm — a potentially valuable commodity for refractories use.

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52. Vermiculite in the Stanleyville Area, Lanark County, Eastern Ontario

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INTRODUCTION

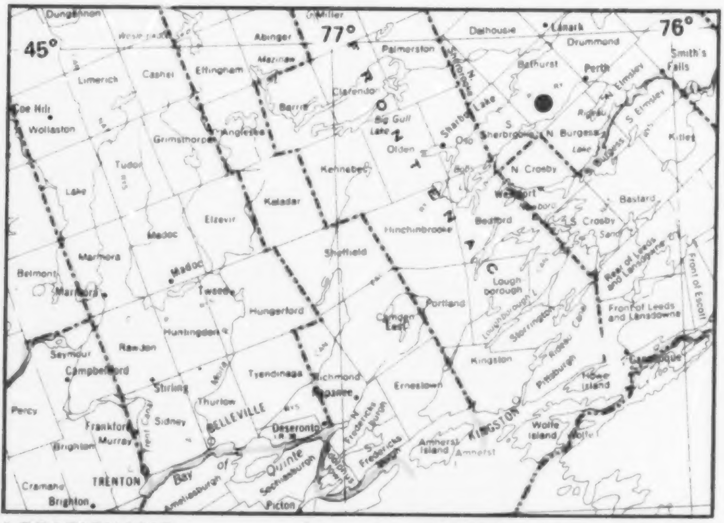
Vermiculite occurrences are widely distributed throughout the Stanleyville-Pike Lake area of Lanark County in Eastern Ontario (Location Map and Figure 1). These include two large deposits hosted by pyroxenites, the Olympus Mines Limited (now owned by Canada Resources Limited) and the Norden Vermiculite Deposit. Numerous smaller occurrences are found as veins and disseminated mineralization in marbles. Other deposits throughout Ontario, while different in age, show features in common with those of Eastern Ontario so that the particular examples at Stanleyville can be used as a means of understanding processes of formation, and lead to improved forecasting. The Eastern Ontario deposits, although extensively tested in the 1960s as aggregate for gypsum plaster, remain largely unassessed. Now, because good domestic and overseas market opportunities exist for suitable vermiculite deposits (Beauregard 1982), this project was initiated to map the geology of the known vermiculite occurrences and test potential prospects with ground magnetometer surveys. The project was jointly funded by the Resident Geologist's Office, Eastern Region (Ontario Ministry of Natural Resources), and the Mineral Deposits Section, Ontario Geological Survey, Ontario Ministry of Northern Affairs and Mines.

MARKET OUTLOOK FOR VERMICULITE

Several indicators suggest that a new producer of vermiculite might be successful on the world market. Four major sources, 3 in the United States and 1 in South Africa, together produce 94% of the vermiculite consumed by the Western World (525 000 tonnes in 1981). North America consumes over 60% of the Western World production (Dickson 1982). Since consumption within the United States balances production, the needs of Canadian industries (32 380 tonnes in 1981) and those of the European block are serviced by a single mine in South Africa, the Palabora Mining Company's operation at Loolekop. The consumer's exfoliating plants across the Western World are, therefore, vulnerable to interruptions of supply and to a price structure firmly controlled by the supplier.

Against this background, there is both growth in traditional markets and broadening range of uses for vermiculite. Within North America, markets for agricultural uses of vermiculite have increased in the last decade. In this sector, vermiculite represents about 33% of total demand in the United States, and in Canada its position has risen from 20% of total demand in 1981 (Dickson 1982) to 50% (Beauregard 1982). This market has more successfully survived the recession of recent years than the larger market in construction.

In agriculture, vermiculite is used as a carrier of soil nutrients enabling small amounts of trace or minor elements to be distributed evenly; as an inert bulking agent in animal feed; and as a carrier of fats and fat-soluble vitamins in animal fodder. In horticulture (representing about 7% of total consumption in the United States), vermiculite is used in potting soils to improve aeration and water retention of soil mixtures. In Canada, horticultural use represents 40% of the consumer market (Canadian Minerals Yearbook


45°
77°
76°
Dungannon
Limerick
Cashel
Effingham
Abinger
Miller
Palmerston
Dalhousie
Lanark
Drummond
Smith's Falls
Bathurst
Perth
Wollaston
Grimsthorpe
Anglesea
Barrie
Clarendon
Olden
Kennebec
Kaladar
Elzevir
Madoc
Marmora
Belmont
Tweed
Hungerford
Huntingdon
Rawdon
Seymour
Campbellford
Sidney
Thurlow
Tyendinaga
Richmond
BELLEVILLE
Deseronto
Frankford
Murray
Brighton
Cramahe
TRENTON
Bay of Quinte
Picton
Sheffield
Hinchinbrooke
Bedford
Loughborough
Portland
Camden East
Kingston
Ernestown
Amherst Island
KINGSTON
Wolfe Island
Pittsburgh
Storrington
Westport
N. Crosby
S. Crosby
N. Burgess
S. Sherbrooke
Bastard
Kitley
Rear of Leeds and Lansdowne
Front of Leeds and Lansdowne
Front of Escott
Gananoque
Percy
Lake
Tudor

LOCATION MAP Scale : 1 : 1 548 000 or 1 inch to 25 miles

1985) and can reasonably be expected to grow at about 5% per annum.

In Canada traditional uses of vermiculite have declined from 55% in 1981 to 30% in 1983 (Canadian Minerals Yearbook 1985). This has been partly offset by research which has developed new applications including sprayable fire-proofing for the domestic, industrial, and marine sectors; substitutes for asbestos-bearing mixtures and polyurethane foam in response to health concerns, and vermiculite-coated fibreglass capable of withstanding 1000°C. These all represent higher technology, value-added uses for vermiculite. Beauregard (1982) estimated a Canadian market requirement of 30 000 tonnes (concentrate) per year. Trends of consumption (Canadian Minerals Yearbook 1985) which give imports varying from 35 700 tonnes in 1981 through 21 000 tonnes in 1983, to 84 200 tonnes in 1984 confirm this view.

There exists potential for expansion of the vermiculite trade into international markets. Supply disruptions in South Africa could leave the European block ready to accept a new producer. While Japan and Brazil are producers, these countries have deficits or potential deficits which must be supplemented by imports. India and Argentina also consume all internal production, and will require greater tonnages as they become more industrialized.

Thus political instability, concerns about the safety of traditional lightweight refractory insulation (asbestos, polyurethane), and changing technology have had a stimulating effect on the vermiculite market and therefore it is timely to re-evaluate known deposits in Ontario.

GENERAL GEOLOGY

The geology of the Stanleyville area comprises Grenville Supergroup metasediments, Late Precambrian intrusive rocks and Paleozoic rocks (Figure 1).

The Grenville Supergroup in the map area can be subdivided into calcareous metasediments (calcareous or dolomitic marble and pyroxenite) and clastic metasediment (quartzite and quartzofeldspathic gneiss). Since the metamorphic pyroxenite is host to significant vermiculite development, this rock unit was mapped in detail.

Emplacement of Late Precambrian intrusions was accompanied by metasomatism and doming of the adjacent sedimentary rocks (Wilson and Dugas 1961). There exists a gradual zonation from massive syenite, syenite gneiss, syenite-migmatite, and finally unaltered garnet gneiss from the centre of each plutonic body outwards. Syenite-migmatite represents a transitional phase between rocks of igneous and sedimentary origin (Wynne-Edwards 1967). Wilson and Dugas (1961) believed that quartzite was transformed into granite and garnet gneiss into syenite through chemical re-adjustment during the granitizing process that formed the syenite-migmatite complex. This same process presumably supplied the silica required to alter the dolomitic marble into a pyroxenite, and influenced the change of phlogopite into vermiculite.

The undulating Precambrian erosional surface was unconformably overlain by a variable thickness of the Cambro-Ordovician Nepean Formation, which has protected the soft pyroxenite and vermiculite beneath. Glaciation has subsequently removed the caprock, exposing these friable alteration products at surface.

Some indication of a post-Grenvillian, pre-Nepean erosional event is locally recorded. This may have influenced vermiculite formation. Wilson and Dugas (1961) described a conglomerate on the western shore of Rideau Lake 8 km west of Stanleyville which appears to be of this age interval and differs from Nepean conglomerate. Twenty kilometres to the northwest, the Playfair (Dalhousie) iron mine contains pyrite pervasively oxidized to hematite (Rose 1958), an effect which could also be attributed to deep weathering.

OLYMPUS PROPERTY

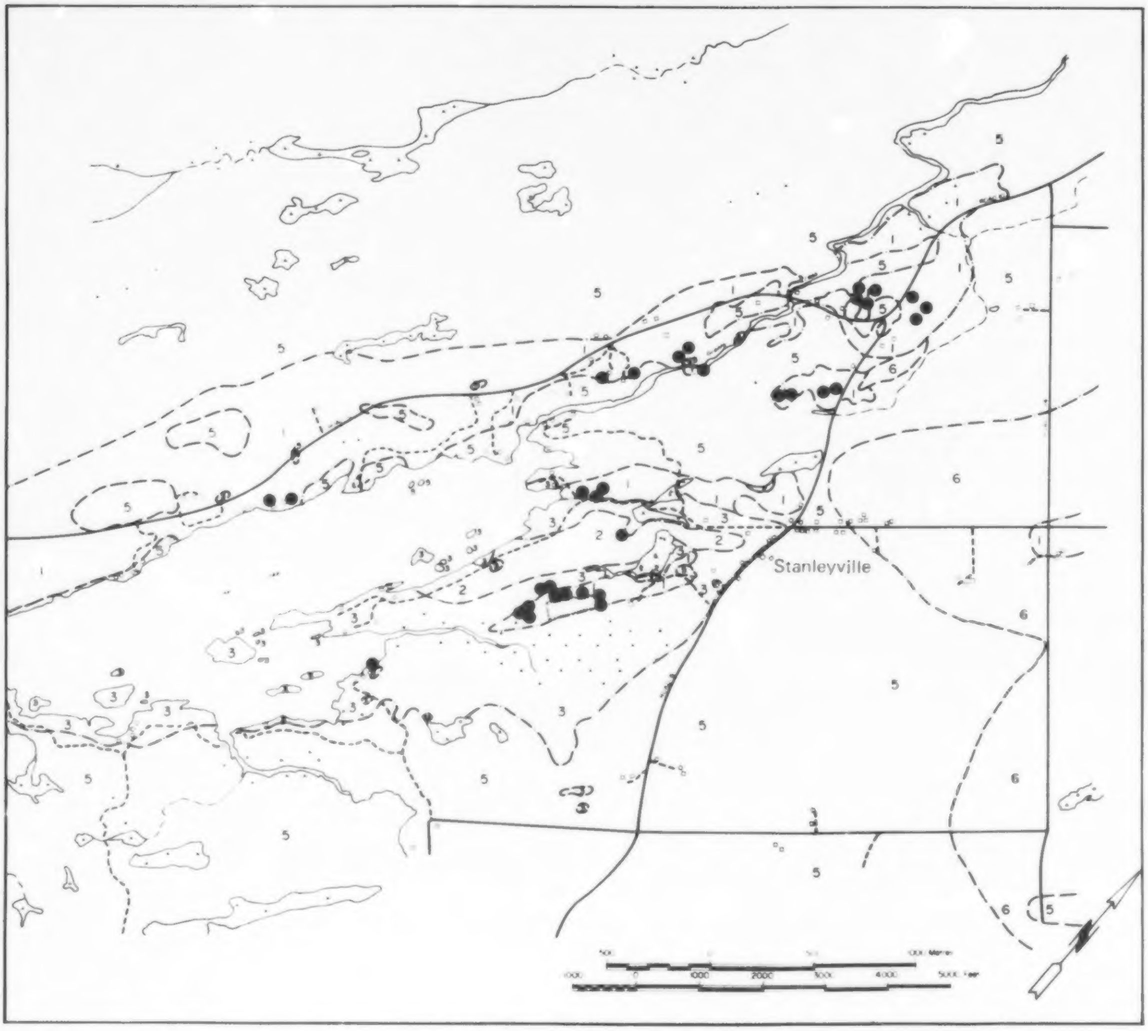
The Olympus property was chosen as a type example for study. It is located on the northern half of lots 17 (includes 100 acres of patented land) and 18, concession 8, North Burgess Township, approximately 0.8 km southwest of Stanleyville and approximately 12.8 km by road from Perth, Ontario (Figure 1). The Canadian Pacific Railway's main line passes through Perth.

EXPLORATION HISTORY

In 1950, G.C. Bruce of the Industrial Minerals Branch, Ottawa, discovered the deposit. Siscoe Vermiculite Mines Limited, a new subsidiary of Siscoe Gold Mines Limited, optioned the property a few days later and engaged in a program of auger drilling, test pitting, and trenching. In 1959, the property was sold to Olympus Mines Limited. The company began developing the property in June 1960 by drilling 45 auger holes and 2 diamond-drill holes. By 1963, an open pit measuring 1000 feet by 300 feet by 20 feet had been excavated and a stockpile with an estimated 165 000 tons of vermiculite-bearing material produced. A processing plant was constructed by 1965 and some material was processed, but the operation proved uneconomical and a Mechanic's Lien was taken out against the company. In 1968, it was sold by the court to a consortium in Ottawa. Worldwide Energy Company Limited optioned the ground and retained GHD Consultants of Toronto to evaluate the property in 1969. They drilled 4 holes, totaling 1896 feet, and trenched approximately 2000 feet. A 1000 pound and a 10 000 pound bulk sample were taken from the eastern face of the pit. The 1000 pound sample was sent to Montreal for analysis and the 10 000 pound sample, for a batch test in the existing plant. Results of these tests are not available. The property is currently owned by Canalex Resources Limited (Cunningham 1969; Guillet 1962).

GEOLOGY

In the immediate vicinity of the property, the Grenville Series rocks are paragneisses, quartzite, crystalline limestone and dolostone, and metamorphic pyroxenite. Vermiculite occurs in a thinly banded, pale blue-green, "serpentinized" metamorphic pyroxenite. The pyroxenite is flanked on both sides by a horn-



LEGEND

PHANEROZOIC
CENOZOIC
QUATERNARY
PLEISTOCENE AND RECENT
Sand, gravel, clay, erratics

UNCONFORMITY

PALEOZOIC
CAMBRO-ORDOVICIAN
6 Nepean Formation, quartz sandstone

UNCONFORMITY

PRECAMBRIAN
LATE PRECAMBRIAN
FELSIC TO INTERMEDIATE INTRUSIVE ROCKS
5 Granite, gneissic to massive texture, in places migmatitic, cut later by pegmatitic dykes
Syenite, quartz syenite, syenite migmatite, may contain remnants of paragneiss, cut later by pegmatitic dykes
Diorite
GRENVILLE SUPERGROUP METASEDIMENTARY ROCKS
Clastic Metasediments
3 Quartzofeldspathic paragneiss, may contain garnet, biotite and/or disseminated graphite
Hornblende feldspathic paragneiss, may contain garnet and minor biotite

Quartzose Metasediments
2 Pure quartzite, paragneisses consisting of interbedded quartz and brown crystalline limestone, or interbedded tremolite actinolite ± talc and quartz
Calcareous Metasediments
1 Phlogopitic marble, dolomitized phlogopitic marble, white to buff in colour, fine to coarse grained, may contain disseminated graphite
Diopsidic marble, dolomitized diopsidic marble, white to buff in colour with serpentinization of some diopside grains
Metamorphic pyroxenite, light greenish colour, may contain tremolite, talc, phlogopite, serpentine or vermiculite
Marble, dolomitic marble, fine grained crystalline texture, dirty brown colour

PIT
— — - — GEOLOGICAL BOUNDARY (defined, assumed)
● VERMICULITE OCCURRENCE

***Figure 1.** Vermiculite occurrences near Stanleyville, Ontario. Unit 4 has been omitted for reduction. (Project 52.)*

blende or biotite paragneiss which changes to quartzite northwest of the pit and disappears into swampy ground in the southeast.

The main mineralized zone strikes 052° and dips 80° northwest and can be observed along the northeastern face of the pit. Diamond drilling by GDH Consultants in 1969, established an average width for the zone of 39 m (130 feet) varying between 24 m (80 feet) and 45 m (150 feet), and a minimum length of 420 m (1400 feet). Trenching showed that in the centre of pit the vermiculitized zone is only 24 m (80 feet) wide (Cunningham 1969). The mineralized zones consist of thin bands of pale brown vermiculite-rich rock <2.5 cm wide, alternating with almost barren, altered diopsidic rock. The vermiculite flakes are usually <0.3 cm in diameter, and may vary in colour through pale brown, amber, olive-grey, and silvery. In addition to the banded and disseminated vermiculite found within the main zone, there are vertical veins of coarser grained vermiculite up to 8 cm across. This feature is evident on both the northeastern and northwestern faces of the pit but is more prevalent on the northwestern face. Three additional vermiculite-bearing zones of limited extent occur on the property (Guillet 1962).

The hanging wall grades into relatively hard, competent, cream-grey, unaltered diopsidic pyroxenite and the contact between it and the main zone is irregular due to interbanding of the vermiculitized pyroxenite with barren pyroxenite. This is evident on the surface and in samples obtained from the current drill program. Northwards the dominantly diopsidic pyroxenite becomes enriched in tremolite occurring as brown, prismatic, vitreous grains. The pyroxenite is interbanded conformably with quartzite and actinolite-tremolite talc schists.

The main zone is dissected by undulating, horizontal and occasional vertical fractures and intruded by dioritic dikes. The fractures are generally <10 cm thick and filled with grey-blue, massive to fibrous talc. Fibrous talc may pseudomorph serpentine, thus accounting for its increased hardness (Wolfson 1980).

Near the present surface, the host pyroxenite is highly friable, resembling sand in texture and appearance. It is composed of varying proportions of diopside, tremolite, talc, serpentine, phlogopite, with minor iron oxides, calcite, and pyrite. The greenish-white diopside is medium grained, subhedral to anhedral in habit, and has a woody appearance. Thin section examination indicates an intergrowth with amber, euhedral to subhedral tremolite. A brown alteration along fractures and cleavages within the diopside has been identified by electron microprobe analysis as talc stained with iron oxides (Wolfson 1980).

Near the top of the section, there are several indications of a later alteration episode. For example, the top 30 to 40 feet is looser and more weathered than the rocks below. This can be observed in (a) drillcore, (b) the pit face where diorite dikes in the main zone have been partly serpentinized and chloritized and weather an orangish colour staining the pit face, and (c) thin sections, where alteration products (e.g. talc) are observed to be dusted or stained with iron oxides. This alteration decreases from the present surface downwards and from its distribution it appears to be the result of weathering.

Wilson and Dugas (1961) and Rose (1958) presented incidental evidence of erosion and weathering before the Paleozoic, and it is possible that today's surface is in part the re-excavated Precambrian unconformity underlain by material generated during pre-Paleozoic weathering. This may be important in understanding the distribution of the vermiculite because the proposed paleoweathering surface closely defines its position stratigraphically. Examples from other vermiculite deposits such as those at Libby, Montana (Boettcher 1966), and South Carolina (Libby 1975) suggest that high-grade metamorphism produces biotite or phlogopite from which vermiculite is subsequently formed by meteoric waters under weathering conditions.

BENEFICIATION TRIALS

R. Collings and J.M. Lamothe (Research Scientists, Mineral Processing Laboratory, Canada Centre for Mineral and Energy Technology, personal communication, 1985) are conducting beneficiation tests on one 350 pound chip sample and on split drillcore obtained from the Olympus Mines Limited property during this project. The core represents the interval 40 to 143 feet as the top 40 feet were too friable to recover. These tests will involve the examination of different methods of separating the vermiculite from its host minerals either before or after exfoliation. Air tabling, magnetic or electrostatic separation, and wet processing are the most promising methods. The size fractions obtained and the flake size distribution will indicate what the different products are best suited for and will suggest how a competitive, energy efficient product can be achieved.

The chip sample, taken from the cleaned northeastern face of the pit, rich in vermiculite, comprised five 10-foot lengths of about 70 pounds each. Core samples of a deeper section of the mineralized zone were obtained from an inclined drillhole striking 140° and dipping 57°, that is, parallel to the northeastern pit face. The hole was drilled to a vertical depth of approximately 143 feet and is 171 feet in length. From the split core, half was shipped to the Tweed Core Storage Facility and half was sent to CANMET for testing purposes.

MINERALOGICAL TESTING

Some vermiculite deposits are known to contain fine grained particles which are hazardous to health. From this point of view, a representative sample aggregate from the Stanleyville deposit was examined by E.J. Chatfield (Ontario Research Foundation, personal communication, 1985). Complete data will be more fully reported later but essentially the material contains a very minute concentration ($<1.06 \times 10^{-5}$% by weight of unprocessed ore) of cylindrical flakes formed by alteration of phlogopite. In length these flakes (on average 0.5 to 0.73 μm) are well below the 5.0 μm size that are of concern as a dust hazard. A very low concentration of various amphiboles is also present (1.52×10^{-2}% by weight), but overall this material does not appear to have the characteristics that are known to be of concern to health.

GEOPHYSICAL SURVEY

A ground magnetometer survey was conducted around the Olympus Pit, using a Geometrics '826' proton precession magnetometer (accurate to 1 gamma). Approximately 6.1 km of line was traversed with line spacing of 50 m and stations at 10 m intervals.

The main objects were first, to trace vermiculite pods and lenses associated with stringers and dikelets using geophysical techniques, and second to determine the location of buried lithological contacts which otherwise have been estimated by extrapolation from outcrop areas. There was minimal success in locating contacts and none in delineating the vermiculite zones. This was due to topographic limitations (a large swamp is located on the eastern side of the pit where the source of the dikelets and stringers was expected), and insufficient contrast between the magnetic susceptibilities of the different lithologies north of the pit.

SUMMARY

1. An extensive zone of vermiculite mineralization occurs within pyroxenite on the Olympus Mines Limited property. Previous drilling established an average width of 39 m (130 feet), a length of 420 m (1400 feet) for the mineralized zone to a depth of 95 m (300 feet).
2. Vermiculitization on the Olympus Mines Limited property is inferred to be due to hydrothermal alteration of phlogopite. However, a later alteration effect occurs to a depth of 40 feet below the present surface which may represent weathering at some time since the Precambrian, a process which also may have contributed to the generation and/or present distributions of vermiculite.
3. A ground magnetometer survey was not useful in delineating the vermiculitized zones associated with the syenitic and dioritic intrusions because of insufficient magnetic contrast between the rock units.
4. Beneficiation tests and testing of fibrous minerals are underway. These results are important considerations from an environmental and economic view point and full results will be included in a forthcoming Open File Report.
5. To date, the mineralogy and fibre content of the vermiculite indicate no similarity to materials of known health concerns.

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53. Building Stone – Eastern and Algonquin Regions

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INTRODUCTION

Fieldwork for the Building Stone – Eastern and Algonquin Regions Project was in progress at the time of writing this summary. An extensive report on this work and the results obtained will be released on Open File at the Toronto and Regional Offices of the Ontario Ministry of Natural Resources or the Ontario Ministry of Northern Affairs and Mines as soon as the work is completed, during the Winter of 1985-86.

In recent years the building stone industry has enjoyed a period of growth, particularly in exterior stone cladding applications. This is primarily due to the modernization of processing facilities, improved marketing strategies, the trend towards use of durable weather resistant building materials by designers and architects, and a renewed appreciation of the aesthetic appeal of natural stone.

R.H. Singleton (1980) predicts an increase in demand for dimension stone at an average rate of 1.4 % per year from 1978, to the year 2000, in comparison to an average 2.5 % per year decrease in demand during the last 20 years. This trend reversal is based primarily on the fact that many alternate building materials, including concrete, aluminum, and steel which are energy intensive to produce will rise in cost with increasing energy prices.

In view of the present increase in demand for building stone, the Ontario Ministry of Natural Resources has initiated a program of preliminary investigation of building stone potential of parts of Eastern, Algonquin, and Sudbury Regions, possibly to be followed up by future building stone projects.

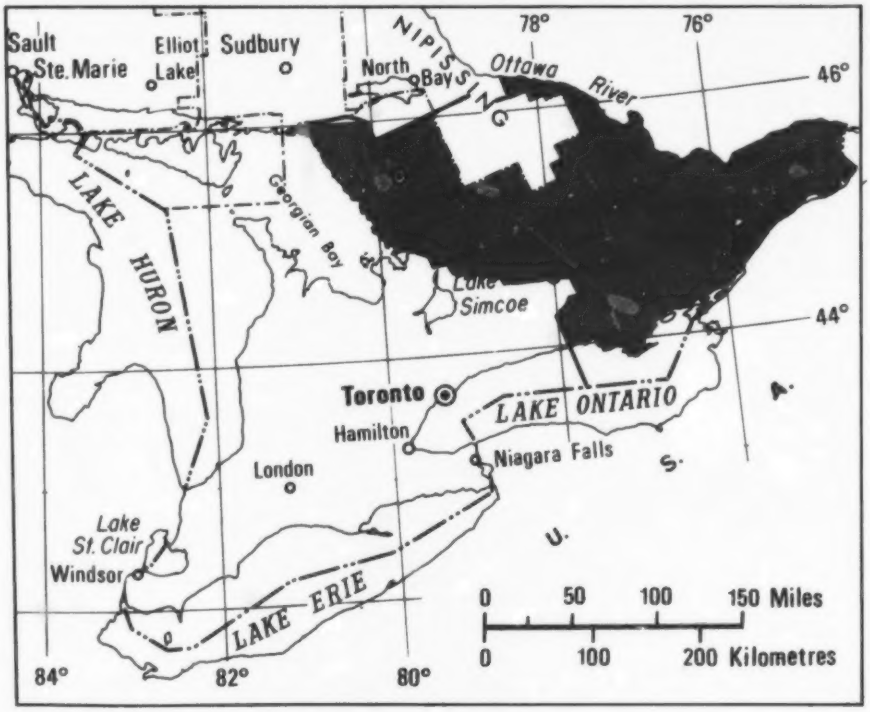
In the present study, approximately 85 building stone properties of past and present producers in Eastern Ontario and Algonquin Regions have been examined. New areas with development opportunities have been delineated. Limited reconnaissance work was also directed at the North Bay-Powassan, Mattawa, and French River areas of Sudbury Region. Emphasis is directed at commercial granite suitable for monument stone, exterior stone cladding applications, and curbing stone, although other applications such as flagstone, ashlar, terrazzo, decorative stone, and crushed stone were considered. Paleozoic rocks and marbles were included in the study.

The rocks were assessed in terms of colour, texture, joint patterns, grain size, composition and overall consistency. Follow up petrographic work is being carried out. The results of this work as well as an outline of the overall potential of various areas, will be published shortly in an Open File Report.

THE GRENVILLE PROVINCE

The present study is confined to the Grenville Province and Paleozoic rocks of Eastern and Central Ontario.

The Grenville Province is characterized by high grade regional metamorphism (reaching granulite facies in places), and general northeast-trending structures. Marbles are a distinctive metasedimentary rock of the Grenville Supergroup (Wynne-Edwards 1972).



The present investigation of Grenville rocks is confined to the Central Metasedimentary Belt and the Central Gneiss Belt of Eastern and Central Ontario.

CENTRAL METASEDIMENTARY BELT

The Central Metasedimentary Belt is dominated by rocks of the Grenville Supergroup. These rocks consist of marbles, clastic metasediments, and metavolcanics. They are intruded by mafic to felsic plutonic rocks, some of which are identified as being either late or postdating the major phase of tectonism known as the Grenville Orogeny. Structure trends in a northeasterly direction and the regional metamorphic grade ranges from greenschist to granulite facies.

Several known marble deposits were investigated mainly in the Madoc-Marmora, Bancroft, and Renfrew areas. Calcitic and dolomitic marbles of lower greenschist to lower amphibolite facies regional metamorphism and marbles metasomatically altered by adjacent intrusions show the best potential. Coarse-grained, white to buff, dolomitic marbles of middle to upper amphibolite facies regional metamorphism also represent good exploration targets.

Since most of the commercial granite deposits hosted by Grenvillean rocks in Quebec occur in granulite facies regional metamorphic zones (Verschuren *et al.* 1985), field investigations of commercial granite deposits were concentrated along the Frontenac Axis, where regional metamorphic grade also attains granulite facies. Pink to brownish quartz monzonitic rocks in the Lyndhurst area and dioritic rocks west of Charleston Lake indicate good potential for dimension stone extraction in this region which hosts the only producing granite dimension stone quarries in Eastern Ontario, i.e. the Battersea Quarry north of Kingston and the Cloutier quarries at Straw Hill. Future work in this area should further delineate areas of interest.

Also examined were the Coe Hill granite in Wollaston Township and syenitic rocks 3 km east of Lasswade in Chandos Township. The latter are pink to pinkish grey in colour and fine to medium grained. Vertical to inclined jointing is sparse in some locations; however, closely spaced (0.3-1.0 m) horizontal sheeting is prevalent. These rocks appear to split very cleanly in various directions and may be suited for the manufacture of curbing stone.

CENTRAL GNEISS BELT

The Central Gneiss Belt of Ontario which is exposed throughout most of the Algonquin Region is characterized by upper amphibolite facies regional metamorphism (locally granulite facies) and general northwesterly trending structures. The dominant rocks in the Central Gneiss Belt are quartzofeldspathic gneisses and migmatites of primarily clastic sedimentary origin. These rocks are typically heterogeneous in nature and best suited for ashlar, flagstone, and crushed stone products.

Fine- to medium-grained, pink, grey to brown granitic and charnockitic intrusive rocks occur northwest of Parry Sound, in the French River area, and near Port Carling.

PALEOZOIC ROCKS

Field examinations of Paleozoic rocks were restricted to the thickly bedded limestone of the Bobcaygeon Formation which outcrops extensively throughout Eastern Ontario. Limestone quarries were examined in the Tweed, Marmora, Pakenham, and Kingston areas. The colour of the limestone ranges from brown and dark grey to black and produces attractive stone when cut.

ACKNOWLEDGMENT

This project is equally funded by the Resident Geologist's Office, Tweed, Ontario Ministry of Natural Resources, and the Resident Geologists' Offices of Huntsville and Bancroft, Ontario Ministry of Northern Affairs and Mines.

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INTERDISCIPLINARY PROGRAMS

The Opapimiskan Lake Project

The Black River-Matheson (BRIM) Program

S54. Opapimiskan Lake Project: Precambrian and Quaternary Geology of the North Caribou Lake Area, District of Kenora, Patricia Portion

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INTRODUCTION

The Opapimiskan Lake Project is a three-year integrated geoscience survey of the North Caribou Lake Belt, an area of Archean supracrustal rocks which forms part of the Sachigo Subprovince in northwestern Ontario. The purpose of the project is to update and expand the geological database available on this area, and to assess its largely unexplored mineral potential.

In 1984, the first year of the project, Ontario Geological Survey (OGS) activities included bedrock and surficial mapping which began in the northwestern part of the project area, mineral deposit and aggregate assessment studies, and reconnaissance till prospecting for gold. These activities were reported by Breaks *et al.* (1984).

In the first part of 1985, the North Caribou Lake Belt was covered by a geophysical program including airborne electromagnetic and total field magnetic surveys. Maps based on these surveys were recently published (OGS 1985).

During the 1985 field season, bedrock and surficial mapping continued to the southeast of the areas surveyed in 1984. Preliminary findings are summarized in this report; preliminary maps based on these surveys will be released in the first part of 1986.

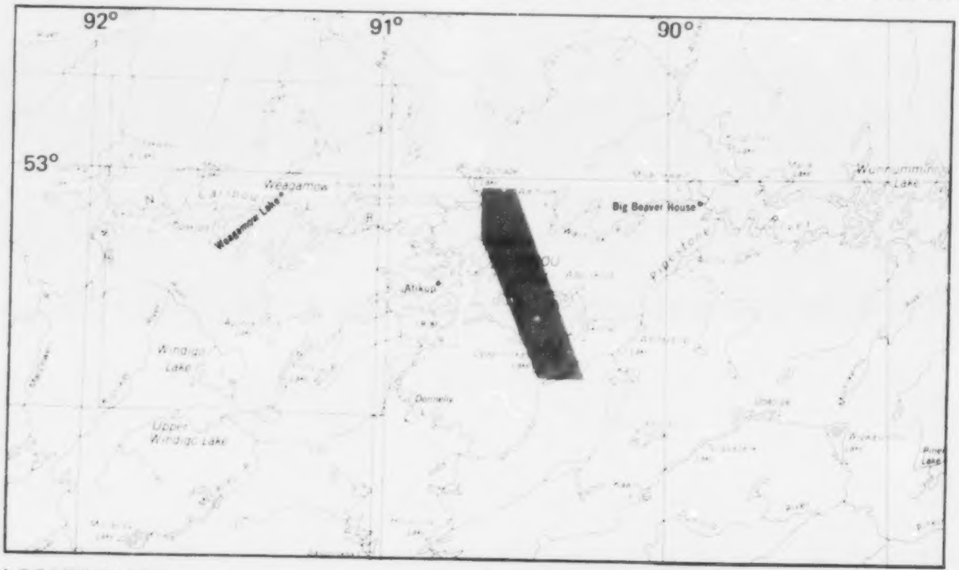
The next article (Piroshco and Shields, this volume) describes detailed studies of mineral deposits in the western part of the belt.

Following the third and final year of the Opapimiskan Lake Project, the results of all geological, geophysical, and mineral deposits studies will be released in one comprehensive report on the North Caribou Lake region.

PRECAMBRIAN GEOLOGY

Mapping by the authors in 1984 in the Eyapamikama Lake area (Figure 1) confirmed the general disposition of map units as put forth by Satterly (1941). Breaks *et al.* (1984) named the clastic metasedimentary sequence medial to the North Caribou Lake Belt the Eyapamikama Lake Metasediments; it is flanked to the north by the North Rim Metavolcanics, and to the south by the South Rim Metavolcanics. As these major lithologic units extend contiguously into the 1985 map area, reference to them in this report is made using the 1984 names.

Mapping in 1985 continued from the eastern boundary of the 1984 area (Breaks *et al.* 1984), and focused upon the south-southeast trending part of the North Caribou Lake Belt between the eastern end of Eyapamikama Lake and Opapimiskan Lake. Complete coverage of the belt between these lakes was hindered by inclement weather. Bedrock exposure is minimal between Eyapamikama and Lundmark Lakes;



LOCATION MAP

Scale : 1: 1 548 000 or 1 inch to 25 miles

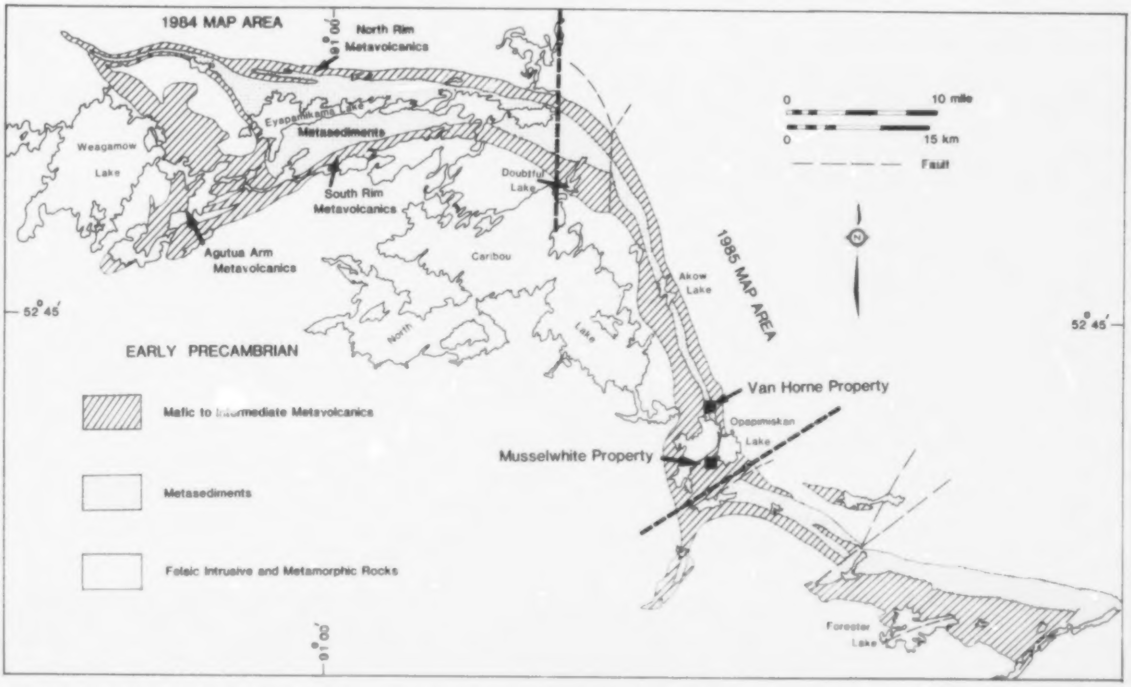

1984 MAP AREA
91°00′
North Rim Metavolcanics
Eyapamikama Lake
Metasediments
Weagamow Lake
South Rim Metavolcanics
Agutua Arm Metavolcanics
Doubtful Lake
Caribou
North
Lake
Akow Lake
1985 MAP AREA
0
10 mile
0
15 km
Fault
N
52°45′
52°45′
EARLY PRECAMBRIAN
Mafic to Intermediate Metavolcanics
Metasediments
Felsic Intrusive and Metamorphic Rocks
Van Horne Property
Opapimiskan Lake
Musselwhite Property
Forester Lake
91°00′

Figure 1. General geology of the Eyapamikama-Opapimiskan Lakes area, showing 1984 and 1985 map areas, and properties mentioned in text. (Project S54.)

this region is part of an extensive southwest-trending drumlin field. Areas of good exposure occur north and northwest of Opapimiskan Lake, between Hatch and Erichsen Lakes, and north of Akow Lake.

In general, geological units interpreted by Satterly (1941) were found to be valid for the map area, although minor modifications were made regarding spatial disposition of supracrustal units and the southwest and northeast contacts with bounding granitoid terrains. For example, the width of the North Caribou Lake Belt in the vicinity of Hatch Lake is approximately 0.8 km greater than was previously interpreted by Satterly (1941).

MINERAL EXPLORATION HISTORY

The earliest exploration activity in the general area was a staking rush following discovery of a gold-bearing quartz vein on nearby Upper Windigo Lake, circa 1928 (Satterly 1941, p.27). The map area witnessed only sporadic exploration until the early 1960s when Rio Tinto Canadian Exploration Limited and the International Nickel Company of Canada Limited both undertook major reconnaissance programs designed to test massive sulphide, nickel, and gold potential (Assessment Files Research Office, Ontario Geological Survey, Toronto (AFRO)). A complete summary of this work and other early exploration is given in Thurston *et al.* (1979, p.74-97). Breaks *et al.* (1984) summarized all past exploration activity, including recent work.

In 1962, discovery of gold by the Musselwhite brothers at Opapimiskan Lake in highly deformed banded iron formation (Thurston *et al.* 1979, p.85-86) renewed interest in the North Caribou Lake Belt. Recent development work by a joint venture group involving Dome Mines Limited, Dome Petroleum Limited, Campbell Red Lake Mines Limited, Sigma Mines (Quebec) Limited, Canadian Nickel Company Limited, Esso Minerals Canada, and Lacana Mining Corporation (The Northern Miner Press; October 1, 1981) included excavation of a decline to examine subsurface geology. The decline was allowed to flood in 1985, however, ground work, including line cutting and surface geology, was performed during the 1985 field season by the above-mentioned group of companies.

Van Horne Gold Exploration Incorporated/Moss Resources Limited conducted a 12-hole, 1500 m diamond drilling program in the summer of 1985 (The Northern Miner Press; September 16, 1985).

Large claim blocks were staked southeast of Doubtful Lake, in the Lundmark-Akow Lakes area, and north of Opapimiskan Lake in 1985 by Moss Resources Limited, Van Horne Gold Exploration Incorporated, Four Square Syndicate, Marietta Resource Corporation/Van Horne Gold Exploration Incorporated (joint venture), and Santa Maria/Van Horne Gold Exploration Incorporated (joint venture) (H.J. Hodge, President, Moss Resources Limited, Toronto, personal communication, 1985).

GENERAL GEOLOGY

North Rim Metavolcanics

This predominantly mafic metavolcanic sequence progressively narrows in a south-southeast direction, varying in width from 2.6 to 0.7 km. A previously undocumented thin (170 m) mafic metavolcanic septum bifurcates from the main belt about 1.5 km north of Hatch Lake and was traced northwards for at least 1.7 km.

The North Rim Metavolcanics have been pervasively subjected to intense deformation and overprinted by medium-grade metamorphism. Consequently, preservation of primary textures, structures, and readily mappable features is exceedingly poor. In a few localities, highly flattened pillows with L:W ratios up to 50:1 are recognizable, for example, 1 km northeast of Hatch Lake. However, most pillows have probably been tectonically segmented via severe stretching and boudinage. Pillow selvedges are usually conspicuous as locally garnetiferous, dark green to black hornblende-rich zones, 0.5 to 2 cm thick.

North Rim Metavolcanics are commonly layered; typically, 0.5 to 6 cm thick light yellow-green, epidote-rich and/or black hornblende-rich layers alternate with fine to medium grained nematoblastic hornblende + plagioclase, amphibolitic layers. Tight to close mesoscopic, disharmonious Z-folds with near vertical axial planes and southeast-trending, shallowly plunging hornblende mineral stretching lineation deform this layering and are particularly commonplace throughout this map unit.

Felsic to intermediate metavolcanics were encountered in a few scattered localities such as 0.6 km northeast of Hatch Lake, and may vary in thickness from 5 to 50 m. These locally garnetiferous rocks are highly deformed, recrystallized, and appear to be nonfragmental.

South Rim Metavolcanics

Within the 1985 map area, the South Rim Metavolcanics form the western edge of the North Caribou Lake Belt. This predominantly mafic metavolcanic sequence has an average thickness of 3 km, however, it is attenuated in a few places, and is tectonically thickened to about 5 km in the Opapimiskan Lake area. Exposure is generally poor, except in the area immediately north of Opapimiskan Lake, and on shores and islands in the southern part of Doubtful Lake.

South Rim Metavolcanics comprise mainly fine to medium grained pillowed and massive mafic flows. Pillowed flows are more common in the northern one-third of the map area. Slightly deformed pillows range to 4 m in length, averaging <1 m, and locally indicate northeast-facing stratigraphy. Chloritic selvedges up to 1 cm thick are commonly separated by accumulations of alteration materials, mainly quartz and plagioclase and/or epidote which also occupy inter and intrapillow spaces.

Moderately to strongly foliated chloritic mafic flows exhibiting few primary structures predominate in the area north of Opapimiskan Lake. Also included in this area are finely laminated mafic rocks, and medium grained hornblende-porphyroblastic flows. Rocks in this area commonly contain minor disseminated sulphide mineralization, and locally display sulphide staining on the weathered surface.

In general, the degree of deformation in the South Rim Metavolcanics increases southerly, as evidenced by stronger pervasive foliations, and greater number of discrete mappable shear zones. In the area east and south of Doubtful Lake, deformation appears to increase towards the contact with the Eyapamikama Lake metasedimentary sequence, as evidenced by more highly flattened pillows. Deformation is generally not as intense as in the North Rim Metavolcanics.

The South Rim Metavolcanics host numerous quartz ± plagioclase ± epidote ± tourmaline ± sulphides veins, commonly concordant to the predominant foliation in the host rock, and generally associated with most shear zones greater than several centimetres in width. Pervasive carbonate alteration has affected massive and pillowed mafic flows and a mafic dike in the Doubtful Lake area. The close proximity of these altered rocks to the contact with known and inferred iron formation may prove to be significant in terms of gold potential.

Metawackes and rare intermediate volcaniclastic rocks occur within the South Rim sequence southwest of Akow Lake. East of Doubtful Lake, an actinolite-rich, possibly ultramafic rock, appears to be interlayered with mafic metavolcanics.

Eyapamikama Lake Clastic Metasediments

These rocks occupy the axial part of the belt, gradually tapering south-southeastward from 3.6 km wide at the western boundary of the map area to 0.7 km in the Akow Lake area. No exposures were encountered between Eyapamikama and Lundmark Lakes. Extent of this unit was thus based upon coincidence with a pronounced aeromagnetic depression (OGS 1985, Aeromagnetic Maps 80728-80731, 80735-80739).

In the Akow Lake area, intensely porphyroblastic, knobby-weathering metapelites and subordinate metawackes similar to those at the eastern end of Eyapamikama Lake are exposed. Coarse, pink-grey andalusite, measuring individually up to 4 by 6 cm, and 5 by 21 cm as crystal aggregates, dominate the porphyroblastic population in the metapelites and can compose up to 40% of the rock. Ovoid cordierite poikiloblasts up to 4.5 by 8 cm commonly coexist with andalusite and are co-linear to S_0-S_2 bedding/cleavage intersection lineations. Dark brown euhedral staurolites up to 2 by 3 by 13 mm occur in these metapelites in a few places; their random orientation, and overprinting of andalusite and cordierite suggests a post-tectonic derivation for the staurolite.

Andalusite locally exhibits clear signs of sinistral rotation of an early internal S_1 foliation which is discordant to a later S_2 planar fabric in the muscovite-biotite-quartz-plagioclase matrix enveloping the porphyroblasts.

Intercalated metawacke units 6 to 48 cm thick consist mainly of fine grained, biotite-quartz-plagioclase assemblages which locally contain fine grained garnet and medium to coarse grained cordierite porphyroblasts.

TABLE 1 BANDED IRON FORMATION ENCOUNTERED IN THE STUDY AREA. (PROJECT S54).

BIF	Type	Interpreted Strike Length	Maximum Magnetic Relief
Akow-Eyapamikama Lakes	silicate + oxide facies	26 km	4 250 gammas
Doubtful Lake	no known exposure	>7 km	1 500 gammas
Hatch Lake	only chert-rich exposure at south end observed	18 km	2 250 gammas
Opapimiskan Lake	silicate + oxides facies	30 km	6 500 gammas

Chemical Metasediments

Chemical metasediments are extensively developed in the map area, and are almost exclusively hosted by mafic-ultramafic sequences of the North and South Rim Metavolcanics. Four major banded iron formations (BIF) were delineated mainly on the basis of aeromagnetic data (OGS 1985, Aeromagnetic Maps 80719-80723, 80728-80731, 80735-80740).

Some features of these BIF units are summarized in Table 1.

The Akow-Eyapamikama Lakes BIF is one of the most extensive in the map area. Exposures are only known between Lundmark and Akow Lakes and along the southwestern shore of Eldorado Lake. Thickness ranges from 10 to 47 m and averages 35 m. A prominent aeromagnetic anomaly exhibiting a pinch-and-swell shape coincides with this BIF in the Akow Lake area (OGS 1985, Aeromagnetic Maps 80735-80739). This configuration appears to relate to boudinage on a macroscopic scale within the chemical sedimentary rocks. Rocks in neck zones of lower magnetic intensity have undergone conversion of magnetite into grunerite to a greater degree than rocks associated with adjacent magnetic highs. Exposures in the vicinity of these aeromagnetic constrictions exhibit intense, mesoscopic, asymmetric boudinage of chert layers marked by sinistral rotation of boudins up to 20° relative to the strike of enclosing grunerite-rich layers.

The presence of grunerite in the Akow-Eyapamikama Lakes BIF correlates with these zones of increased boudinage and shearing. The latter commonly parallel iron formation banding and axial planes of F_2 folds. Sulphide mineralization, conspicuously evident as numerous small gossan patches, commonly <1 m by 1 m surface area, shows a preferential association with these gruneritic zones. Notable structural features controlling disposition of sulphides include:

1. thin pyrrhotite lenses (<5 mm wide) along the axial plane cleavage of F_2 folds,
2. neck zones between boudinaged chert layers,
3. chert-grunerite bedding contacts in the vicinity of F_2 folds,
4. pre-F_3 thin shear planes (attitude 300-310°/45-85°NE).

Conversion of magnetite to grunerite is also notable on a local scale in progressing from limbs to crests of F_2 folds in the BIF and at the No. 2 Musselwhite gold showing.

A second generation of grunerite is subtly present, developed as ovoid, radiating crystal aggregates which overprint the S_2 planar fabric. Grunerite of this type also occurs as 1 to 3 mm wide reaction rims between chert and iron-rich layers.

Staurolite-rich quartz arenite is exposed immediately west of the aeromagnetically extrapolated grunerite-magnetite-chert BIF north of Lundmark Lake in a 40 m wide unit traceable for about 0.5 km. This massive to weakly foliated, medium grained rock contains approximately 40% dark brown, anhedral staurolite, 40% quartz, and 20% subhedral plagioclase. This unique lithology may provide a useful marker horizon in diamond drill assessment of structure and potential mineralization associated with BIF in the Lundmark Lake area. Subordinate intercalations of intensely foliated, 0.13 to 3 m wide, muscovite-garnet-chlorite porphyroblastic metapelite are also present in some places.

Representative exposures of the Hatch Lake and Doubtful Lake iron formations are virtually absent and hence location of these units is almost exclusively based upon aeromagnetic interpretation. One chert-rich exposure near the southern limit of the Hatch Lake BIF is situated on a small unnamed lake 1.3 km east of the eastern end of Lundmark Lake.

Carbonate Metasediments

One minor (1 to 3 m wide) unit of dolomitic carbonate-rich metasediments was encountered 0.6 km east-northeast of the northeastern end of Hatch Lake. This rock is a tectonic breccia composed of round to angular fragments of massive vein quartz (10% of rock, ranging from 2 by 2 mm to 2.5 by 14 cm) embedded within a light grey-weathering dolomite ± garnet ± diopside matrix. The breccia is enclosed within gneissic, felsic to intermediate metavolcanics. This unit should be investigated further, as anomalous gold values are associated with a similar rock type near the southwestern end of Castor Lake (Breaks *et al.*, in preparation). This specific area is associated with a small elliptical aeromagnetic anomaly of 1000 gammas maximum relief.

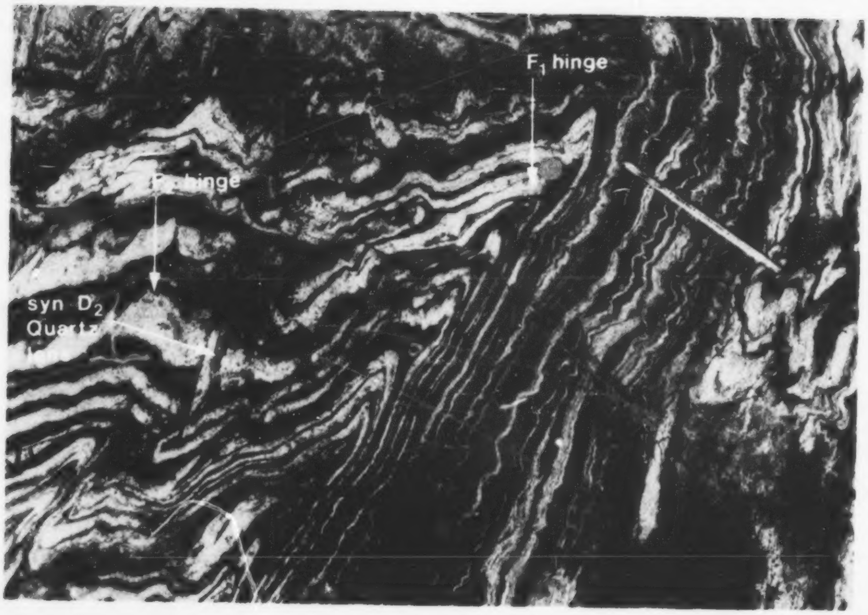


Photo 1. *F$_1$ tight to isoclinal folds in magnetite chert BIF (hinge marked by coin) refolded by F$_2$ open folds (marked by arrow) with associated axial planar cleavage and quartz lenses. F$_3$ folds (parallel to pencil at right) are responsible for Z-shaped, open buckling, mainly in limb areas of earlier folds. No. 1 gold showing of Musselwhite property. (Project S54.)*

Metaplutonic Rocks

The North Caribou Lake Belt is bounded to the west by the North Caribou Lake Batholith, a predominantly tonalitic body that is, in places, gneissic. Near the contact with the South Rim Metavolcanics, the intrusive rocks commonly contain xenoliths of mafic metavolcanic material.

To the east, the belt is bounded by tonalitic intrusive rocks that vary from massive to gneissic. In the Erichsen Lake area, close to the contact with the North Rim Metavolcanics, some metaplutonic rocks have been mylonitized.

Both metaplutonic bodies are cut by myriad granitic pegmatite dikes.

METAMORPHISM

Metamorphic grade increases from southwest to northeast between Eyapamikama and Akow Lakes. Regional isograds delineated in the western Eyapamikama Lake area (Breaks *et al.* 1984) show continuity into the present study area.

Metapelitic rocks are very rarely exposed, however, rocks at the eastern end of Eyapamikama Lake and Akow Lake have similar metamorphic assemblages, featuring coexistence of cordierite + andalusite + muscovite suggesting temperatures of 540°C and a load pressure of <3 kb.

Mafic metavolcanics of the North Rim Metavolcanics show progressive conversion from an epidote-chlorite-actinolite assemblage to a dark green to black hornblende + plagioclase amphibolite towards the contact with the tonalitic batholith to the northwest.

Most of the South Rim Metavolcanic suite is lower grade, mainly contained within the chlorite zone.

STRUCTURAL GEOLOGY

The structural evolution of the North Caribou Lake Belt has involved at least three phases of folding and two shearing events.

The earliest deformation (D$_1$) can be documented in rare situations, and recognized as refolded isoclines in BIF (Photo 1), or as rootless intrafolial folds in quartz veins hosted by ultramafic and mafic metavolcanics in the Opapimiskan Lake area.

Initial morphology of F$_1$ folds is difficult to assess, as their present isoclinal shapes are probably the result of rotation of fold limbs in parallelism with F$_2$ fold limbs.

D$_2$ deformation represents the major tectonometamorphic event in the North Caribou Lake Belt. This is manifested as penetrative, close to open, asymmetric Z and S mesoscopic folds with near vertical axial planes and interlimb angles typically between 70° and 100°. A somewhat variable orientation is notable. In most of the map area, F$_2$ fold axes and associated lineations trend southeast with shallow plunges (4° to 30°). In the Opapimiskan Lake area, F$_2$ fold axes trend northwesterly, with plunges ranging from 10° to 35°. In BIF exposures, fold morphology remains relatively consistent despite changes in fold axis orientation. Examples of F$_2$ folds are shown in Photo 1 and Figure 2.

Characteristic of F$_2$ folds is a strong axial planar cleavage which may either parallel or radiate outwards from the bisecting surface, and is especially prominent in grunerite-rich bands. This fabric commonly guides replacement by thin quartz veins.

In more ductile rocks such as metapelites, ultramafic metavolcanics, and chlorite-rich mafic metavolcanics, the D$_2$ event is mainly apparent as a penetrative S$_2$ foliation. In a few places, this is verifiable as a surface which has sinistrally rotated and

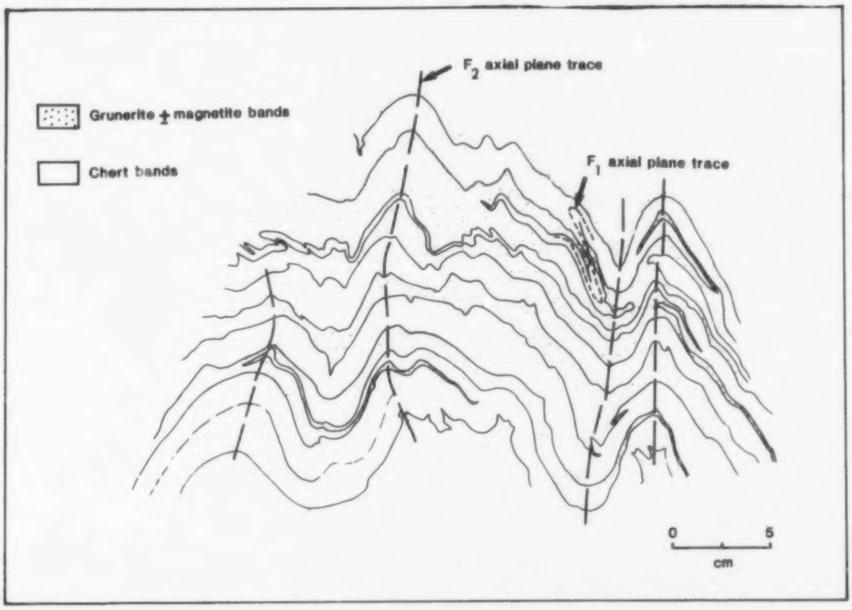


Figure 2. *Profile view of F_2 folds in grunerite-chert BIF from 'Grunerite' Island, Opapimiskan Lake. Refolded F_1 isoclines can be locally discerned. Undulations along chert-grunerite interface due to smaller scale F_3 superposed folds. (Project S54.)*

wrapped around D_1 garnet and andalusite porphyroblasts which contain an internal S_1 planar fabric.

Accompanying penetrative linear fabric elements are defined by mineral and pillow stretching, S_0-S_2 intersection in BIF, F_2 fold hinges, and boudin neck lines.

This axial planar fabric is in a few cases the locus of syn-D_2 shearing in BIF. East of Lundmark Lake this period of shearing is prominent along axial planes and limb areas of F_2 folds and correlates with an increase in sulphide staining and grunerite content. At the Musselwhite No. 1 gold showing, a tectonized zone of grunerite-chert BIF which is enriched in gold, pyrite, pyrrhotite, and arsenopyrite parallels nearby axial planes of F_2 folds and is warped by superposed F_2 folds.

Macroscopic F_2 folds are evident on the Musselwhite and adjacent Van Horne Gold Exploration Incorporated property. Gold mineralization at Everway and Musselwhite Nos. 1 and 2 showings are macroscopically contained within BIF near the crest zones of antiforms (Andrews *et al.* 1981). These folds may attain interlimb spacing of approximately 250 m.

The D_2 event coincides with a period of medium-grade metamorphism. Garnet porphyroblasts and biotite are clearly oriented along an S_2 planar fabric in several outcrops of BIF in the Opapimiskan Lake area.

The D_3 deformation event is only locally penetrative. It is mainly evident as mesoscopic, asymmetric, F_3 folds which are open (90° to 125° interlimb angle), Z-shaped, with vertical axial planes. F_3 folds are most obvious in BIF as on the Musselwhite property and in the Lundmark Lake area. Macroscopic equivalents of these folds were not recognized. Associated S_3 cleavage is only weakly developed and exclusively confined to grunerite-rich layers in BIF on the Musselwhite property.

F_3 folds overprint F_2 folds as at the Musselwhite No. 1 showing (Photo 1), causing broad warps in chert and magnetite-rich layers, and chevron folds in adjoining grunerite-rich bands.

Orientation of F_3 folds is also significantly varied. On the Musselwhite property, F_3 fold axes trend 270-300 and plunge 20°-60°; in the Lundmark Lake area, F_3 folds trend 95-107 and plunge at 25°-85°. In this area, F_3 folds have sinistrally rotated D_2 chert boudins enclosed in a grunerite-rich host.

Superposition of F_1-F_2-F_3 and F_2-F_3 fold elements are revealed in several exposures on the Musselwhite property. Interference of F_1-F_2 folds, as on Grunerite Island, Opapimiskan Lake, yields Type 1 basin and dome structural patterns (Ramsay 1967) (Photo 2). Involvement of F_3 folds leads to local open warping of the basins and domes. Superposition of F_2-F_3 folds yields Type 3 patterns of Ramsay (1967). The hinge lines and axial planes of these folds, respectively, plunge 40° and dip 60°.

ECONOMIC GEOLOGY

Approximately 450 specimens were submitted to the Geoscience Laboratories, Ontario Geological Survey, Toronto, for analysis of gold (2 ppb sensitivity), silver, arsenic, antimony, copper, lead, zinc, and in some cases tungsten, boron, fluorine, and lithium. The material currently being analyzed includes metavolcanics and metasediments mineralized with sulphides, quartz veins containing sulphides and/or tourmaline and/or carbonate and/or albite, barren quartz veins, banded iron formation and tourmaline + biotite metasomatic assemblages.

Gold mineralization is now known to occur in five distinct habitats in the North Caribou Lake Belt:

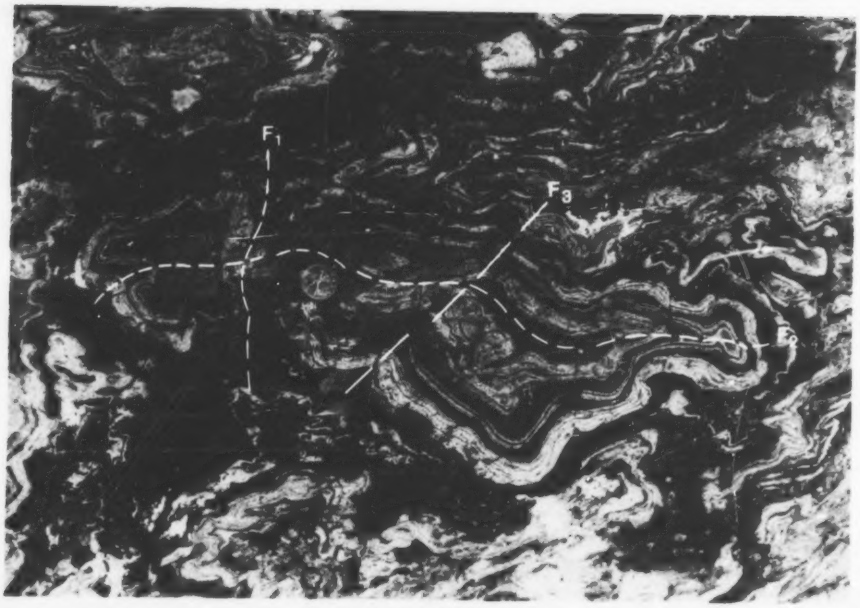


Photo 2. *Spectacular Type 1 interference fold at Grunerite Island, Opapimiskan Lake. Superposition of F_1 and F_2 fold elements results in dome and basin structures. Open warping of this particular basin relates to F_3 influence. (Project S54.)*

1. in quartz veins with locally abundant arsenopyrite, pyrite, and chalcopyrite, hosted in highly carbonatized mafic metavolcanics of the Agutua Arm Metavolcanics (Pyrotex Occurrence) (Bartlett *et al.* 1985);
2. quartz-ankerite vein systems in highly sheared syn-D_2 shear systems in the Agutua Arm Metavolcanics (Teal Occurrence) (Bartlett *et al.* 1985);
3. grunerite-chert ± magnetite BIF in North Rim Metavolcanics at the Musselwhite property on Opapimiskan Lake;
4. quartz-tourmaline-arsenopyrite quartz veins along the contact between North Rim Metavolcanics and Eyapamikama Lake Metasediments (McGruer Lake Occurrence) (Bartlett *et al.* 1985);
5. pre-D_1 tourmaline-quartz veins in South Rim Metavolcanics (Kenpat No. 1 Vein Occurrence, Opapimiskan Lake).

Within the current map area, the best targets for gold mineralization are here considered to be highly deformed silicate-oxide facies BIF and relatively early quartz veins of the Kenpat No. 1 vein type. The main period of gold deposition is apparently syn-D_2, as numerous structural features controlling sulphidation and gruneritization of BIF were formed at that time (*see* Structure and Chemical Metasediments Sections).

Gold mineralization on the Van Horne Gold Exploration Incorporated/Moss Resources Limited property (Figure 1), occurs along northeastern limbs of macroscopic northwest-plunging F_2 antiforms. Values up to 0.09 ounce gold per ton over 3.3 m occur where magnetite-chert BIF lies in contact with ultramafic volcanic rocks (AFRO).

The highest sulphide contents occur in a 1.8 m wide siliceous tectonic zone which contains sheared and brecciated grunerite-chert BIF impregnated by irregular, anastomosing masses of pyrrhotite, pyrite, and arsenopyrite composing 5% to 15% of the rock. Pyrrhotite-rich veins, 0.5 to 1 cm in width also transect the iron formation and converge into the irregular interconnecting masses.

At the Musselwhite No. 1 gold showing, albite-rich dikes intrude grunerite-chert BIF and schistose mafic metavolcanics. These 2.5 to 21 cm wide dikes, which contain accessory tourmaline, biotite, chlorite, pyrite, pyrrhotite, and arsenopyrite, are responsible for boron and potassium metasomatism and possibly sulphidation in the host metavolcanics.

Biotite + tourmaline-enriched endogeneous haloes vary in width from 3 mm to 15 cm in mafic metavolcanics, and from 3 mm to 6 cm in BIF. These metasomatic haloes pre-date F_3 folds, as shown by subtle Z-folds which cause crinkling of biotite. These small scale folds are identical in morphology and orientation to nearby F_3 folds in BIF. The F_3 event is also responsible for local sinistral rotation of boudinaged sections of the albite-rich granitoid dikes.

Endogeneous dispersion of potassium, boron, sulphur, and possibly gold and silver may be an additional factor to consider when exploring for gold in this region. On the Musselwhite property and adjacent areas, pre-D_3 tourmaline and/or biotite segregations and replaced pillow selvedges represent a common, albeit volumetrically minor, component in mafic and ultramafic metavolcanic exposures. The source of these metals may relate to a conduit system, represented by albite-rich granitoid dikes, which emanated from the apical part of a volatile-charged felsic magma centre. The biotite- and/or tourmaline-enriched segregations are currently being geochemically analyzed.

Gold also occurs within early, deformed tourmaline-carbonate-quartz veins. The Kenpat No. 1

Vein, which occurs in highly deformed pillowed and massive mafic metavolcanics of the South Rim Metavolcanic sequence near the northwestern end of Opapimiskan Lake represents the best example of this type of vein. Assays of 0.23 ounce gold per ton over 5.5 m and 0.24 ounce gold per ton over 6.1 m were reported by Burns (1963). A 0.6 m wide zone of potassium metasomatism, featuring conspicuous fine grained biotite, has been imposed upon massive mafic metavolcanics along the southwestern contact of the Kenpat vein.

QUATERNARY GEOLOGY

Areas investigated during the summer of 1985 include the eastern halves of Donnelly River (NTS 53 B/10) and Mawley Lake (NTS 53 B/7) map areas, and the western halves of Forester Lake (NTS 53 B/8) and Opapimiskan Lake (NTS 75 B/9) map areas. Selected localities in the North Caribou Lake (NTS 53 B/15) map area were also examined.

PHYSIOGRAPHY

The study area is part of the Severn Upland division of the James physiographic region (Bostock 1969). The Uplands are relatively flat to gently rolling, strongly reflecting the thinly drift-covered predominantly granitic terrain that underlies most of the region.

Most of the study area lies between 270 and 400 m above sea level, the regional topographic gradient rising from northeast to southwest at a rate of about 3 m/km. Ice-contact complexes, including end moraines and associated deposits, create local relief up to about 30 m. The most prominent example is the Agutua Moraine (Prest 1963), a major glacial feature in northwestern Ontario.

QUATERNARY DEPOSITS

The study area contains a variety of Quaternary deposits that represent the region's last major ice advance and its subsequent retreat during the Wisconsinan. Till, mainly lodgement till, was deposited during the advance of glacial ice, and a variety of ablation deposits, including glaciolacustrine sediments of glacial Lake Agassiz, were deposited as the glacial front retreated northward.

The last and most dominant ice movement to effect the study area was generally south to southwestward as suggested by glacial striae and other ice flow directional indicators. Older west to southwest-trending striae are also preserved on the lee sides of bedrock outcrops near Doubtful and Opapimiskan Lakes. These may be correlative to older northwest-trending striae reported by Prest (1963) east of the study area.

Anomalous striae are present near Opapimiskan Lake. They exhibit random orientations, are not well developed and are not found regionally. It is the opinion of this author that they represent grounding of floating ice.

Till is the most extensive Quaternary deposit present. Texturally, the till is a stony and gritty, silty, fine sand. It is usually moderately compact, fissile, and massive, and occurs in the form of drumlins, end moraine, and ground moraine. Till colour varies from a yellowish brown to brown near the surface; fresh unoxidized exposures are olive or olive-grey. In most locations, fines have been winnowed from the upper 0.5 m of the till by the action of glacial Lake Agassiz.

Glaciofluvial deposits consisting of sand and gravel occur as eskers, kames, and outwash. Eskers are commonly discontinous and compound, forming braided systems that usually occupy regional topographic lows. One such esker system follows the Pipestone River, southwestward, and connects downstream with a delta that forms part of the Agutua Moraine. Kame deposits are commonly associated with esker systems.

Outwash sand and gravel occurs in the form of terraces along many of the present-day river valleys that once served as temporary meltwater channels. Most outwash terraces are limited in size and extent; the most prominent being those along the Paseminon River, near Zeemel Lake.

Varved silts and clays deposited in glacial Lake Agassiz are found scattered throughout the study area, particularly in the Pipestone River valley and along the northern shore of Zeemel Lake. These sediments seldom exceed 1 m in thickness and they are generally found in low sheltered areas, between bedrock knolls and ridges.

Abandoned shoreline features are present in the study area. They occur in the form of beach ridges, wave-cut notches, and boulder lag concentrates. Beach ridges are rare, whereas wave-cut notches associated with a lag deposit of concentrated boulders are common on glacial features that project above the water plane of glacial Lake Agassiz.

Large parabolic dunes up to 15 m in height occur in the southern part of the study area. These features which occur above 350 m above sea level are composed of well sorted fine sand. Their orientation suggests that the paleowind direction was from the west.

The most common types of organic deposits are peat and muck which occur in the form of bogs and fens. The thickness of the organic matter is variable and it commonly overlies glaciolacustrine sediments.

Small roundish pockets of fen have been noted in a few large bogs. These features are probably relict collapse scars that may have formed in thermokarst peat plateaus.

BEDROCK DISPERSION STUDIES

Bedrock dispersion studies in the vicinity of the North Caribou Lake greenstone belt began in 1984 (Breaks *et al.* 1984) and continued during the summer of 1985.

As noted by Andrews *et al.* (1981), the study area is particularly well suited for bedrock dispersal studies since glacial ice movement was transverse to the strike of the Weagamow-North Caribou Lakes metavolcanic-metasedimentary belt. Also, there is abundant coarse glacial drift exposed at the surface and the belt consists of easily recognized and spatially distinct bedrock types (Andrews *et al.* 1981, p.212). Thus, the distribution and nature of glacially transported boulders from the belt were examined and documented. Samples for geochemical analysis of unweathered lodgement till were also collected down-ice from the greenstone areas.

Based on the presence of gold mineralization within iron formation units, particular attention was given to the occurrence and distribution of iron formation float.

High concentrations of boulders occur around the perimeters of most lakes and islands in the study area. Unfortunately, high water levels in 1985 prevented their examination. Boulders were examined inland, however, near known or suspected sources of iron formation bedrock.

Near Opapimiskan Lake, few clasts of iron formation float were found. Most were angular and very large (up to 3 m in diameter); however, little down-ice dispersion could be detected. In comparison, dispersion trains were more readily detected in the western part of the belt. This dispersion variance may be due to the local dynamics of glacial ice and/or the nature and composition of the underlying iron formation bedrock.

Lithologic and geochemical data on boulder and till samples will accompany preliminary maps for this area.

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S55. Geology and Gold Mineralization of the Eyapamikama Lake Area of the North Caribou Lake Greenstone Belt, District of Kenora (Patricia Portion)

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INTRODUCTION

In this second year of the 3 year Opapimiskan Project involving staff from Mineral Deposits, Precambrian Geology, and Engineering and Terrain Geology Sections, the Mineral Deposits Section concentrated its fieldwork in the Eyapamikama Lake Area of the North Caribou Lake Greenstone Belt (Figure 1). The study area is located some 180 km north of Pickle Lake and is best accessed from that community by float equipped aircraft.

PREVIOUS WORK

Geological mapping within the Eyapamikama Lake Area, prior to 1984, is summarized by Breaks *et al.* (1984). During 1984, the Eyapamikama Lake Area was mapped at a 1:15 840 scale by the Precambrian Geology Section (Bartlett *et al.* 1984). The Precambrian mapping outlined a number of areas where problems of stratigraphy and structure were not resolved. These areas were coincident with the location of a number of known gold showings and were also the target of recent staking activity. Also during 1984, the Mineral Deposits Section carried out preliminary examination of the geology and gold occurrences in the belt. Both the Precambrian and Mineral Deposits Studies served as a base for work carried out by the latter in 1985.

PURPOSE OF STUDY

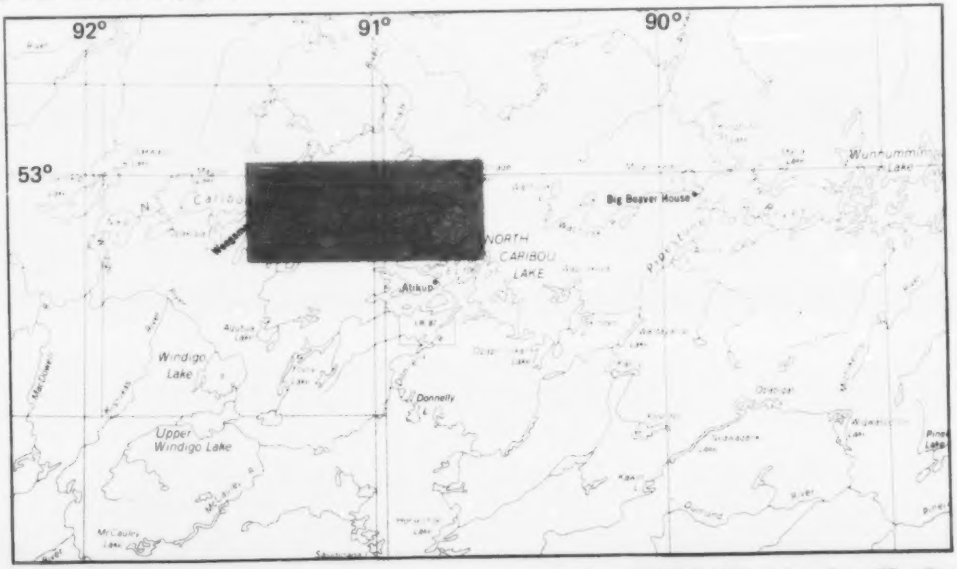
The purpose of this study is to enhance the regional interpretation of the geology of the belt and help characterize the mineral deposits within the belt by determining the controls on localization of mineralization. Emphasis of this study is on both regional and detailed field work and petrographic studies. This summary deals with both the regional and detailed field work components.

MINERAL EXPLORATION

During the 1985 field season geological mapping, lithogeochemical sampling, and prospecting were carried out by Moss Resources Limited on their Randall Lake and Agutua Arm properties (Figure 1). Northern Dynasty Exploration Limited also completed selective geochemical soil surveys on their Agutua Arm, Arseno Lake, Castor-Pollux and McGruer Lake properties (Figure 1). Sulpetro Minerals Limited also carried out lithogeochemical sampling and prospecting on the Teal property and a property to the northwest of Center Lake (Figure 1). Comstate Resources Limited did preliminary geological mapping and lithogeochemical sampling on their property north of Center Lake (Figure 1). A large number of claims scattered about the Eyapamikama Lake Area have been staked by various companies and individuals and recorded with the Mining Recorder's Office in Sioux Lookout.

REGIONAL GEOLOGY

The geology of the Eyapamikama Lake Area of the North Caribou Lake Greenstone Belt is described in Breaks *et al.* (1984). Based on the stratigraphic and structural setting, the area has been subdivided into three domains, referred to hereafter as the Agutua



LOCATION MAP

Scale : 1: 1 548 000 or 1 inch to 25 miles

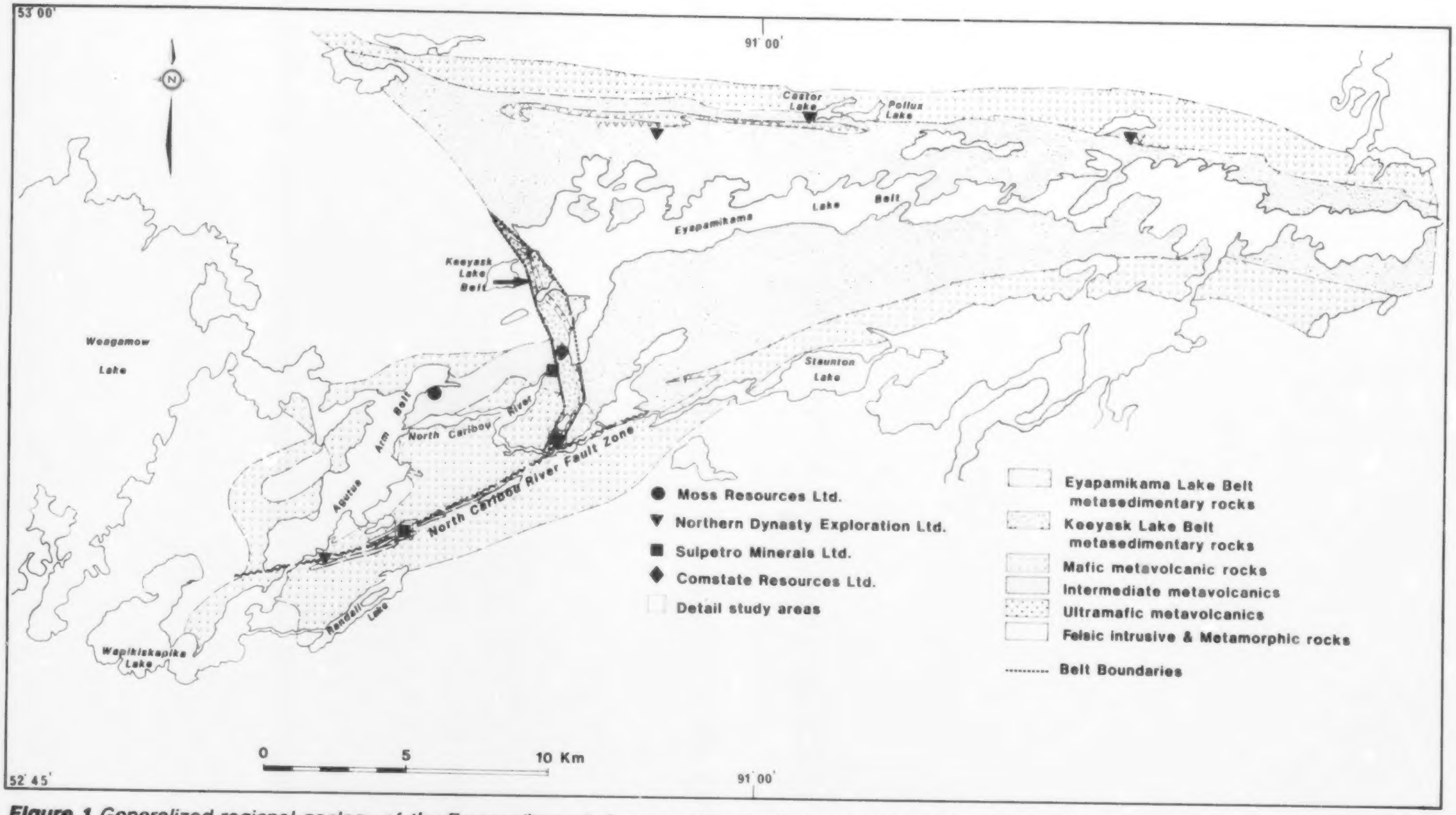

53°00'
91°00'
52°45'
91°00'
N
Weagamow Lake
Castor Lake
Pollux Lake
Eyapamikama Lake Belt
Keeyask Lake Belt
Arm Belt
Agutua
North Cariboo River
North Cariboo River Fault Zone
Staunton Lake
Randall Lake
Wapikiskapike Lake
Moss Resources Ltd.
Northern Dynasty Exploration Ltd.
Sulpetro Minerals Ltd.
Comstate Resources Ltd.
Detail study areas
Eyapamikama Lake Belt metasedimentary rocks
Keeyask Lake Belt metasedimentary rocks
Mafic metavolcanic rocks
Intermediate metavolcanics
Ultramafic metavolcanics
Felsic intrusive & Metamorphic rocks
Belt Boundaries
0
5
10 Km

Figure 1 Generalized regional geology of the Eyapamikama Lake area after Bartlett et al. (1984) showing location of detailed study areas and exploration properties. (Project S55.)

Arm, Keeyask Lake and Eyapamikama Lake belts (Figure 1).

STRATIGRAPHY

The Agutua Arm belt is comprised predominantly of massive but locally pillowed, intermediate to mafic flows (Figure 1). Local intercalations of felsic and intermediate pyroclastic units within the mafic flows suggest a general northeast striking stratigraphy. However, the stratigraphic relationship between the pyroclastics and the mafic flows has not been established. The mafic metavolcanics are intruded by apophyses of the Weagamow batholith as well as a series of northeast striking diorite and gabbro bodies.

The Agutua Arm metavolcanics are unconformably overlain by the Keeyask Lake belt of metasedimentary and metavolcanic rocks. A local, chert pebble conglomerate unit marks the base of the Keeyask Lake Belt and is overlain by trough cross-bedded, quartz arenite which in turn is overlain by stromalitic marlstone followed by thinly bedded to laminated siltstone. The top of the metasedimentary sequence is marked by chert-magnetite banded iron formation (BIF). Directly overlying this metasedimentary sequence is a thick unit of locally spinifex textured ultramafic flows. The ultramafic unit locally interdigitates with overlying pillowed and massive mafic metavolcanics. Polymictic conglomerate, included with the Eyapamikama Lake metasediments by Breaks *et al.* (1984) was found to be intercalated with and overlying the Keeyask Lake volcanic rocks (Eric Dekemp, Graduate Student, Department of Geology, Carleton University, Ottawa, Ontario, personal communication, 1985). Overlying and interstratified with the conglomerates are massive, immature, coarse wackes and feldspathic arenites.

East of the Keeyask Lake belt the metasediments and metavolcanics of the Eyapamikama Lake belt are exposed (Figure 1). The contact relationship between the north trending Keeyask Lake belt and the east trending Eyapamikama Lake belt has not been conclusively established but has been interpreted as an unconformable contact (Breaks *et al.* 1984).

The metasediments of the Eyapamikama Lake belt occupy the centre of the belt and are exposed predominantly on the north and south shores of Eyapamikama Lake. They are rimmed to the north and south by the North and South Rim metavolcanic sequences respectively. The contact between the metasedimentary belt and the two metavolcanic sequences is often marked by chert and banded iron formation. The Eyapamikama Lake metasediments consist of an extensive unit of coarse wackes, feldspathic arenites and thinly bedded mudstones locally intercalated with polymictic conglomerates. The North Rim metavolcanics comprise a 0.4 to 1.7 km thick sequence of pillowed mafic flows with minor intercalations of mafic and intermediate volcaniclastic rocks, chemical metasediments and ultramafic rocks. The South Rim metavolcanics are a similar sequence and also consist of massive and pillowed mafic metavolcanics, with local intercalations of felsic and intermediate tuff and chemical metasedimentary units.

STRUCTURAL GEOLOGY

The major folding event of the Eyapamikama Lake Area was recorded by Satterly (1941). He recognized opposing stratigraphic top indicators on the north and south sides of Eyapamikama Lake and interpreted the metasediments of the core of the sequence to be overlying the peripheral metavolcanic sequences. He thus postulated a large syncline, possibly co-axial with the long dimension of Eyapamikama Lake. Breaks *et al.* (1984) support this interpretation and suggest that this early isoclinal folding event (F1) is related to a regional deformation event (D1) which is also characterized by a penetrative mineral foliation (S1), and transposed bedding and original fabric elements (So) into parallelism with S1 and flattened pillows and conglomerate clasts (L1). They also suggest a D2 event which is characterized by open to gentle folds (F2) with northeast striking, gently to moderately southeast dipping axial planes. The effect of the D2 event is also evident in the development of a pronounced crenulation cleavage (S2) in the mudstones best seen on the shores of Eyapamikama Lake; in other rock types this cleavage is either poorly developed or absent.

The most notable deformation zone recognized in the Eyapamikama Lake Area is the North Caribou River Fault Zone. This deformation zone is intermittently traceable for 15 km from the north shore of Wapikiskapika Lake, northeast to where Staunton Lake narrows into the North Caribou River (Figure 1). The North Caribou River Fault zone shows evidence of both brittle and ductile deformation. Kinematic indicators (i.e. stretching lineations and minor folds) suggest a component of both left-lateral and dip-slip motion (see below).

Breaks *et al.* (1984) recognized a ductile deformation zone along the contact of Eyapamikama Lake belt metasediments and the North Rim metavolcanics. In the Castor-Pollux Lake area, the cherts and banded iron formations are intensely deformed into tight and isoclinal folds. The dislocation of fold limbs and boudinaging of competent units add to the structural complexity of the area.

DETAILED STUDY AREAS

Two areas were chosen for detailed mapping and sampling (Figures 1 and 4), the Teal Property area and the Center Lake Property area. Both of these areas contain relatively numerous outcrops, and coincident gold occurrences.

TEAL PROPERTY AREA

The Teal Property was mapped by St. Joseph Exploration at a scale of 1:2 400 in 1977; this served as a base for mapping carried out during 1985 at a scale of 1:2 500, covering a 1500 m by 800 m area surrounding the Teal occurrence (Figure 2). Two sections across the Teal occurrence (15x 15 m and 15x 10 m) were uncovered and mapped at 1:100 scale. Two outcrops of iron formation (15x 15 m and 20x 5 m), on the southeast shore of the West Lake were also exposed and mapped at a scale of 1:50.

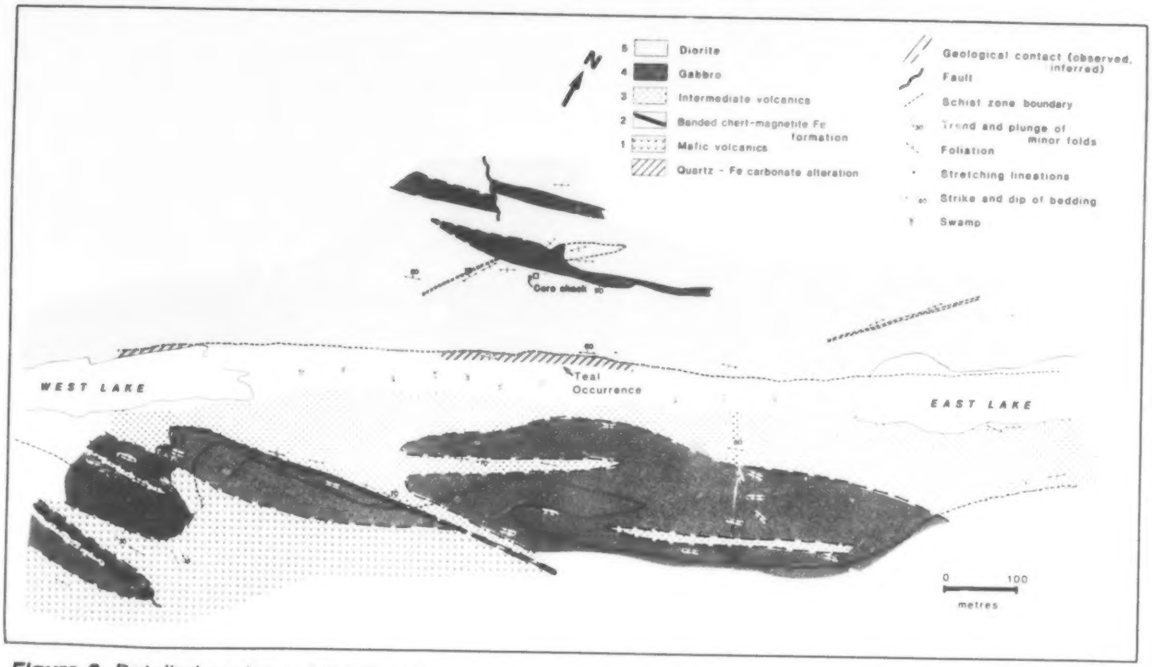


Figure 2. Detailed geology of the Teal Property area. (Project S55.)

Stratigraphy

A 50 m wide, northeast trending overburden covered interval separates two distinct lithological domains at the Teal property. To the south of the overburden covered interval distinct stratigraphic units of the South Rim metavolcanic belt and intrusive units can be mapped. To the north of the overburden covered area, stratigraphic units cannot be mapped. The following description of the stratigraphy is of the southern lithological domain.

Metavolcanics and Metasediments: A southeast to northwest section across the southern lithological domain consists of a sequence of massive mafic metavolcanics (Unit 1, Figure 2), banded chert-magnetite-pyrrhotite iron formation (Unit 2, Figure 2) and massive to plagioclase-phyric intermediate flows/pyroclastic breccia (Unit 3, Figure 2). The iron formation trends northeast, with near vertical dip, ranges in thickness from 2 cm to 3 m and is the only stratigraphic marker.

Intrusive Rocks: In the southern lithological domain, the stratigraphy is intruded by northeast trending, coarse grained gabbro bodies (Unit 4, Figure 2), with individual bodies being less than 100 m wide, containing slices of the intermediate metavolcanics. The gabbro flanks both the northwest and southeast contacts of the iron formation.

In the northern lithological domain, massive diorite predominates (Unit 5, Figure 2). The dioritic unit is medium to coarse grained and varies from diorite to quartz diorite. It is locally intruded by medium grained, northeast trending gabbro dikes.

Structural Geology

In the southern lithological domain, the mafic and intermediate metavolcanics and gabbro are cut by a series of chlorite schist zones less than 25 m wide. Primary features, such as amphiboles in the gabbro and fragments within the intermediate pyroclastic breccia can be traced into the schist zones where they have been elongated and plunge 60° to 70° northeast. On the southeast shore of West Lake, chert-magnetite-pyrrhotite-banded iron formation is deformed into tight folds plunging 60° northeast showing highly attenuated limbs with parasitic folds and thickening at the hinge areas. Intensely developed foliation, trending 070° to 080°, within the gabbro and intermediate metavolcanics flanking the iron formation, is axial planar to these folds. In addition the iron formation is locally boudinaged and exhibits intraformational, small scale, southeast plunging drag folds.

In the northern lithological domain, the diorite is cut by local northeast trending chlorite-calcite or chlorite-iron carbonate schist zones up to 10 m in width. Textures within the diorite can be traced into the schist zones. At the southern boundary of this domain, massive diorite is in sharp to gradational contact with a 12 m wide unit of foliated quartz-iron carbonate chlorite talc-rich rock hosting the Teal Occurrence. Irregularly shaped pods (<2 x 1 m in size) of relatively massive diorite occur within this unit and are in gradational contact with it. The quartz-iron carbonate rich zone is in contact with chlorite-calcite rich rock to the southeast. The contact between these two rock types is marked by a 0.5 m wide quartz-green muscovite vein. An intensely foliated quartz-iron carbonate rich zone of unknown width, exposed on the northwest shore of West Lake, is possibly an extension of the Teal structure.

Mineralization and Quartz-Ankerite Veining

The Teal Occurrence consists of a series of discontinuous, quartz-ankerite-sulphide veins hosted by the quartz-iron carbonate zone. The main sulphides are arsenopyrite, tetrahedrite, chalcopyrite, pyrite and bornite. The veins are parallel to foliation, are boudinaged and locally occur as "sheeted veins" within schistose zones up to 1.5 m wide. Up to 1 percent euhedral to subhedral pyrite and arsenopyrite occur within the quartz-carbonate and chlorite-calcite zones.

CENTER LAKE AREA

The Center Lake area (Randall Lake property) was mapped by Moss Resources Limited at a scale of 1:4 800 in 1985. The map served as a base for detailed mapping at a scale of 1:2 500 by the authors who covered a 1 200 x 800 m area at Center Lake and southwards to the North Caribou River (Figure 3). Several outcrops were uncovered and mapped at 1:50 scale.

Stratigraphy

A 50 to 100 m wide, north-northeast trending overburden covered interval separates two distinct lithological and structural domains at the Center Lake area. To the northwest of the covered interval, distinct stratigraphic units of the Keeyask Lake belt can be mapped. To the southeast of this covered interval a distinctly different stratigraphic sequence occurs, however, several stratigraphic units can be correlated across the covered interval.

To the northwest of the covered interval, the Keeyask Lake stratigraphy, as mapped by Breaks *et al.* (1984) between Center Lake and the portage trail linking Eyapamikama Lake to Pakiagama Lake (Figure 4), can be traced south to the covered interval. Near the southwest shore of Center Lake, a well exposed section of the lower clastic metasedimentary sequence of the Keeyask lake belt occurs in contact with the Agutua Arm belt rocks (Figure 3). At this location a thin (1 cm to 1 m wide) bed of chert and banded iron formation pebble conglomerate occurs at the base of the Keeyask Lake sequence and is flanked, or underlain, to the west by a 10 m thick unit of fractured, pillowed mafic metavolcanics (Unit 1b, Figure 3) which are characteristically bleached yellow (sericitized) and irregularly oxidized on weathered surfaces. This horizon is in gradational contact with unfractured, green-weathered (chloritized) pillowed mafic metavolcanics, and is interpreted by the authors to be a regolith. The thin basal conglomerate is overlain by a 20 to 25 m thick section of massive, trough cross-bedded, mature quartz arenite (Unit 2, Figure 3), overlain in turn by a 3 m thick sequence of thinly bedded siltstone and mudstone (Unit 2b, Figure 3) and a 5 m thick sequence of chert-magnetite banded iron formation. Mafic metavolcanics of unknown thickness overlie the BIF. Cross bedding indicates that the stratigraphy faces east consistently.

On the southeast side of the covered interval two west to east sections across the map area are representative of the stratigraphy. Across these sections rocks of unknown origin occur which can be classified in terms of their anomalous mineralogy as follows: quartz-iron carbonate talc magnetite-bearing rock (Unit 4b, Figure 3), quartz-iron carbonate-chlorite bearing rock (Unit 4c, Figure 3), quartz-sericite schist containing up to 20% quartz eyes (Unit 5a, Figure 3). Unit 4b is interpreted to be ultramafic in origin because of the presence of talc in amounts up to 50%. Unit 4c is interpreted to be mafic metavolcanic in origin because of the textural and mineralogical gradation between this unit and unaltered mafic metavolcanics. Unit 5a is interpreted as intrusive quartz-porphyry in origin because of its local discordancy with stratified units (i.e. BIF) and because of its gradation into undeformed quartz porphyritic rock.

The first west to east section is of the area immediately south and east of Center lake and the second is along the immediate north side of the North Caribou River (Figure 3). In the first section carbonatized mafic metavolcanics (Unit 4c) are flanked by up to 1 m wide beds showing reverse and normal grading from chert and quartz porphyry pebble conglomerate to quartz arenite to siltstone which is exposed near the south shore of Center Lake. The chert pebbles within the conglomerate are subangular to subrounded, averaging approximately 2 cm in diameter and occur within a fine grained, siliceous, gritty matrix. The distribution and extent of the conglomerate unit are not known. The graded beds indicate that the stratigraphy south of the covered interval also faces east. Overlying the conglomerate unit is a 20 to 25 m section of massive quartz arenite which in turn is overlain by a 150 m section of quartz porphyry. The quartz porphyry is in contact with banded chert-magnetite iron formation and in one instance an apophysis of this quartz porphyry was found intruding the iron formation. The thickness of the iron formation is not known (>3 m) but it is flanked by a second unit of a quartz porphyry which is exposed on the southeast shore of Center Lake. The second quartz porphyry unit is in contact with carbonatized ultramafic rocks exposed on the northeast shore of Center Lake. A quartz porphyry 'pod' intrudes the carbonatized ultramafic at this location. In the east, the carbonatized ultramafic is in contact with a 1 to 2 m wide sequence of chert, BIF and chlorite schist. East of the BIF unit, massive, carbonatized mafic metavolcanics occur which grade into relatively unaltered mafic metavolcanics 20 m to the east.

In the second west to east section, located immediately north of the North Caribou River and south of Center Lake, relatively unaltered massive mafic metavolcanics, gradational with carbonatized equivalents, are in contact with a 10 to 15 m thick section of pelitic and arenaceous metasediments. The pelitic metasediments are in contact with a 10 to 15 m thick section of massive quartz arenite which in turn is in sharp contact with quartz porphyry. The quartz porphyry unit is interpreted to be 300 m thick at this location and is flanked to the east by massive mafic metavolcanics.

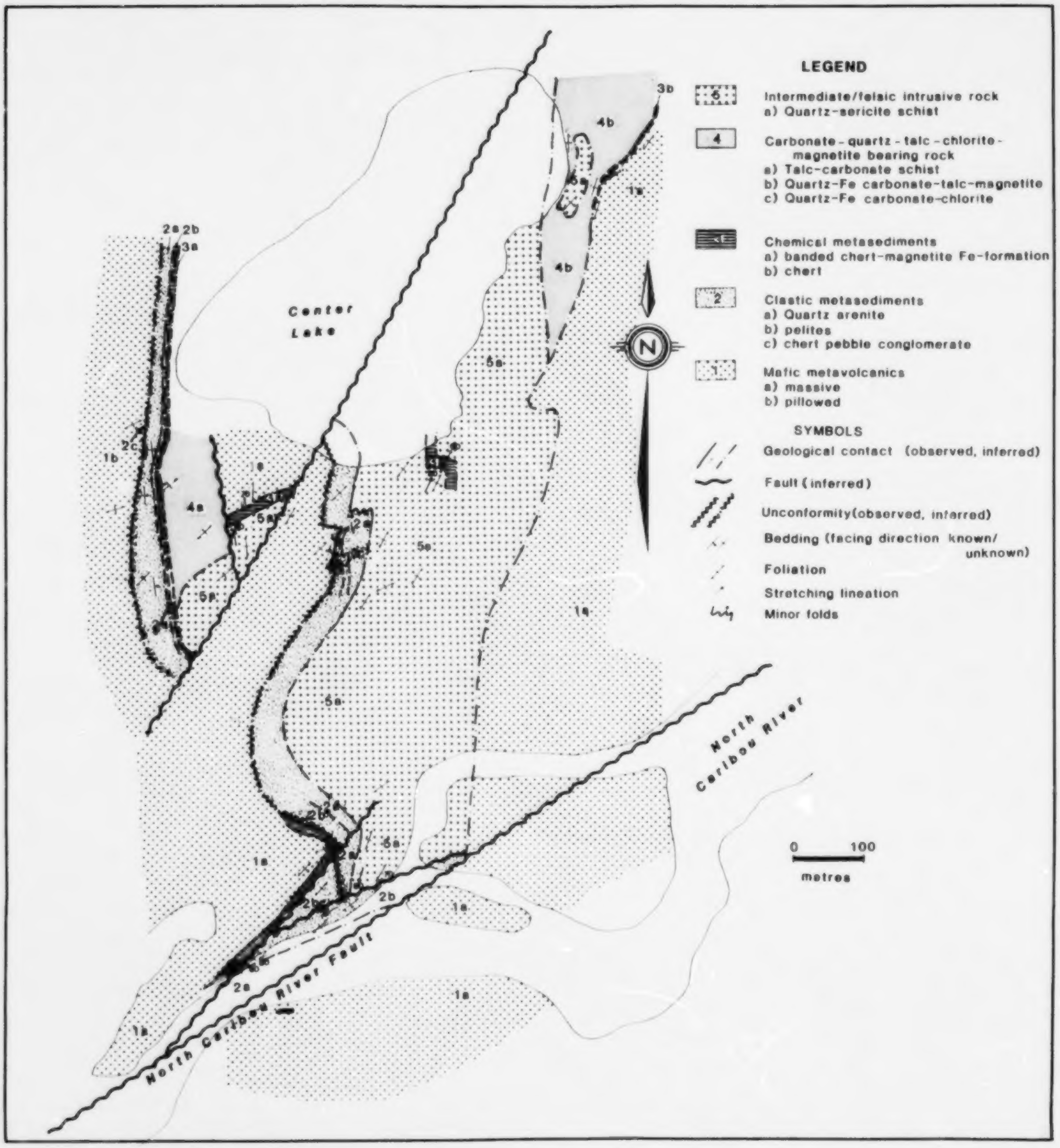

LEGEND
5 Intermediate/felsic intrusive rock
a) Quartz-sericite schist
4 Carbonate - quartz - talc - chlorite - magnetite bearing rock
a) Talc-carbonate schist
b) Quartz-Fe carbonate-talc-magnetite
c) Quartz-Fe carbonate-chlorite
3 Chemical metasediments
a) banded chert-magnetite Fe-formation
b) chert
2 Clastic metasediments
a) Quartz arenite
b) pelites
c) chert pebble conglomerate
1 Mafic metavolcanics
a) massive
b) pillowed
SYMBOLS
Geological contact (observed, inferred)
Fault (inferred)
Unconformity (observed, inferred)
Bedding (facing direction known/ unknown)
Foliation
Stretching lineation
Minor folds
N
0 100
metres
Center Lake
North Caribou River
North Caribou River Fault
1a
1b
2a
2b
2c
3a
3b
4a
4b
5a

Figure 3. Detailed geology of the Centre Lake area. (Project S55.)

Structural Geology

The overburden covered interval which separates the two lithological domains is interpreted to be underlain by a north-northeast trending fault along which the Keeyask Lake stratigraphy has been displaced approximately 400 m in a left-lateral sense (Figure 3). On the immediate north side of the inferred fault, BIF is deformed into small scale open folds plunging 70° north and is locally offset (<10 cm) along north trending right lateral faults. Quartz porphyry exhibiting intensely developed north trending foliation and stretching lineations plunging 80° north flank, the iron formation on its south side. The north trending sedimentary sequence, where exposed, is relatively undeformed with a weak to moderately developed northeast trending foliation.

Southeast of the inferred fault and immediately south of Center Lake the graded conglomerate sequence and the BIF are deformed into tight folds of less than 5 m in amplitude, plunging vertically to 60°

north-northeast. Parasitic folds are common in the iron formation. Chert pebbles within the conglomerate are typically elongate and plunge vertically to steeply north-northeast. The folds are interpreted to occur in the hinge area of a larger scale (25 m) 'S' shaped drag-fold.

A penetrative foliation, best developed in the quartz porphyry, trends 020° to 040°. Locally, up to three penetrative fabrics are present, which consistently trend in the northeast domain, but their relationships and origin are unresolved at present. To the east of Center Lake, penetrative foliation is parallel to the north-northeast strike of the BIF unit. The BIF unit is characteristically intensely boudinaged and deformed.

Stretching lineations are also best developed in the quartz porphyry and plunge near vertical consistently.

Immediately north of the North Caribou River, planar and linear fabrics are similar in orientation and character as described above. Bedding within the pelitic to arenaceous metasediments has been transposed northeast, parallel to the northeast trending foliation and locally buckled into small-scale, chevron folds plunging steeply north-northeast.

At the North Caribou River, the lithological units are locally off-set along northeast trending, bleached, intensely foliated quartz-green muscovite-iron carbonate zones (<3 m wide) and cannot be traced across the North Caribou River. The net slip of the faults is unknown but the lithological units appear to have been rotated in a left-lateral sense into the North Caribou River Fault Zone which coincides with the North Caribou river at this location.

A section of the Keeyask Lake stratigraphy, exposed on the north shore of the North Caribou River, and interpreted to be a rotated block, consists of recrystallized and intensely deformed quartz arenite (trending northeast), buckled and transposed layering plunging steeply southwest, folded lineations on the northeast trending foliation planes, rusty weathered quartz-carbonate lenses, and several northeast-trending quartz-green and white muscovite zones (<0.5 m wide).

To the southeast of the North Caribou River Fault, massive to foliated mafic metavolcanics of the South Rim Metavolcanic Belt occur. To the southwest, along the northeast side of the fault zone, 060 to 080°-trending mafic and intermediate volcanic flows with similar trending units of gabbro and quartz porphyry occur.

Mineralization and Quartz Veining

There are several, narrow, sulphide-rich zones occurring in the Center Lake Area. Along the North Caribou River, south of Center Lake, a narrow quartz-chlorite rich zone (<20 cm wide) contains up to 10% disseminated pyrite and arsenopyrite. East of Center Lake, a 1 x 0.5 m pod of massive pyrite intermixed with chlorite and quartz occurs within a deformed sequence of banded iron formation. Up to 20% disseminated pyrite is also present locally within and along the contact zones of the chert bands. Within the carbonatized ultramafic unit, trace amounts of pyrite and arsenopyrite occur within more quartz rich zones. A 1 m wide discontinuous lens of chlorite-quartz altered rock containing up to 15% disseminated pyrite and pyrite stringers occurs within the carbonatized zone.

Quartz-ankerite veinlets with trace amounts of pyrite and arsenopyrite cross-cut the carbonatized ultramafic and mafic metavolcanics west of Center Lake. Within relatively unaltered portions of the mafic metavolcanics, bleached quartz-iron carbonate haloes with trace amounts of pyrite and arsenopyrite envelope the veins.

The quartz porphyry pod, intruding the altered ultramafics exhibits quartz-and chlorite-rich margins, sheeted quartz veinlets, minor tourmaline stringers and talc inclusions.

Grab samples from the above quartz veined and sulphide mineralized zones have been submitted for gold and trace element analyses.

AGUTUA ARM PROPERTY (PYROTEX SHOWING)

En echelon gold-bearing quartz-arsenopyrite-pyrite-chalcopyrite veins up to 25 cm wide occur in an east trending quartz-carbonate-chlorite rich unit up to 3 m wide on the northeast shore of Agutua Arm. Intense penetrative fabric is absent. An east trending, 1 m wide zone of quartz-iron carbonate-sericite schist is exposed approximately 10 m south of the veins. Textures within massive mafic to intermediate metavolcanic rocks flanking the veins and schist can be traced into these quartz-iron carbonate-chlorite-sericite rich zones.

DISCUSSION

The following discussion integrates the two areas mapped in detail with geological observations made on a more regional scale throughout the map area in 1985 by the authors and by Breaks *et al.* (1984).

THE NORTH CARIBOU RIVER FAULT

The North Caribou River Fault is generally marked by a 50 to 300 m wide zone of intense penetrative deformation which generally occurs within a 200 to 600 m wide zone of predominantly northeast trending dikes intruded into massive mafic and intermediate metavolcanics (Figure 4). Local quartz-iron carbonate-talc-chlorite-rich zones and quartz-green mica veins are common. Northeast of Center Lake, the fault is marked by discontinuous zones of intense penetrative deformation, however anomalously enriched zones of quartz, iron carbonate, sericite and intrusive rocks were not observed.

The lithology of the dikes varies from predominantly coarse-grained gabbro and diorite southwest of East Lake, to predominantly tonalite, diorite, gabbro and lesser quartz porphyry at Discovery Lake (Figure 4). At Discovery Lake quartz porphyry dikes intrude the tonalite and diorite bodies. The relationship between the gabbro, diorite and tonalite dikes is not known.

The penetrative planar fabric within the fault zone is defined by the parallel alignment of platy minerals (chlorite and sericite) and the elongation of

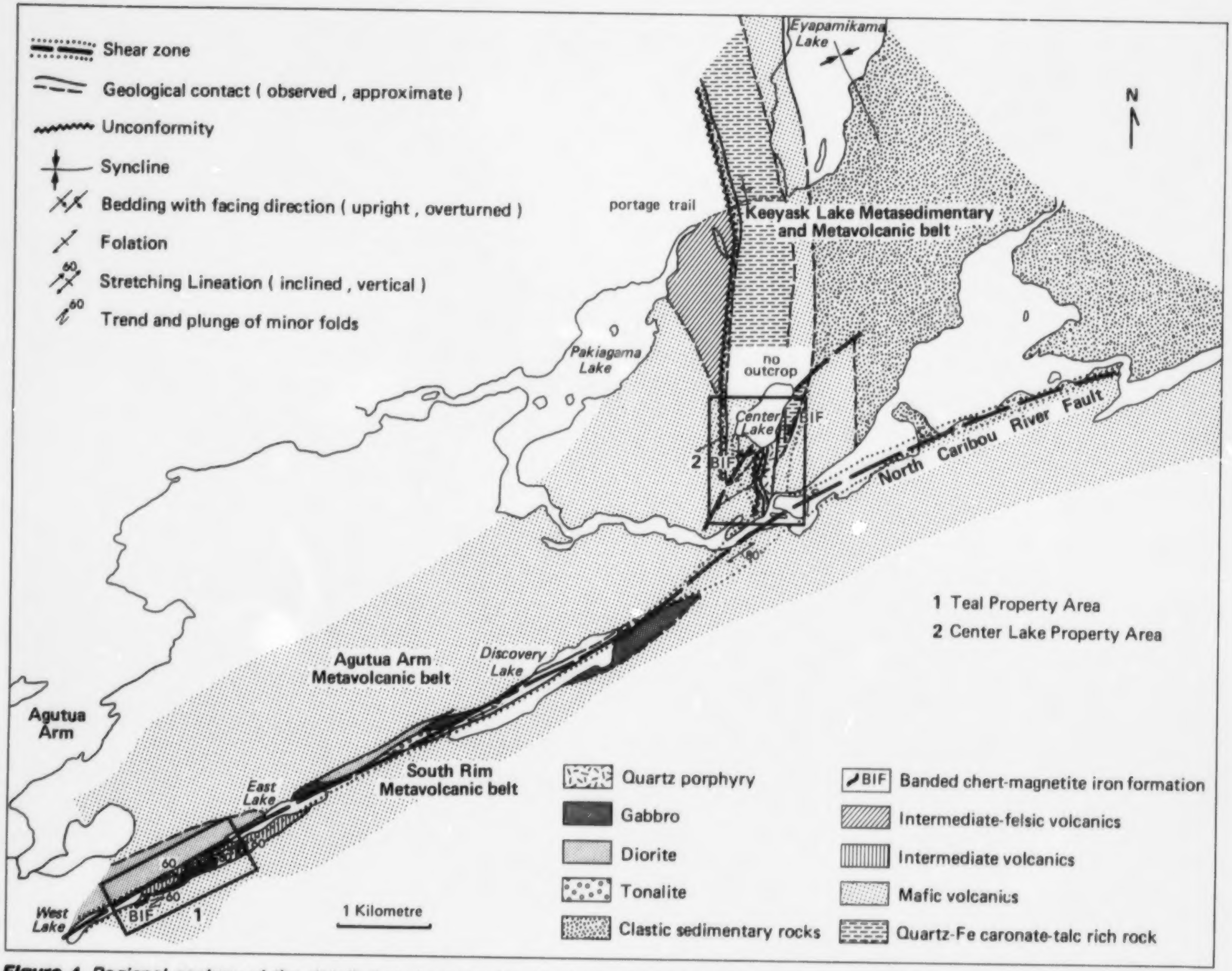

Shear zone
Geological contact (observed , approximate)
Unconformity
Syncline
Bedding with facing direction (upright , overturned)
Folation
Stretching Lineation (inclined , vertical)
Trend and plunge of minor folds
60
N
Eyapamikama Lake
portage trail
Keeyask Lake Metasedimentary and Metavolcanic belt
Pakiagama Lake
no outcrop
Center Lake
BIF
2
North Caribou River Fault
1 Teal Property Area
2 Center Lake Property Area
Agutua Arm Metavolcanic belt
Discovery Lake
Agutua Arm
South Rim Metavolcanic belt
East Lake
West Lake
1
1 Kilometre
Quartz porphyry
Gabbro
Diorite
Tonalite
Clastic sedimentary rocks
Banded chert-magnetite iron formation
Intermediate-felsic volcanics
Intermediate volcanics
Mafic volcanics
Quartz-Fe caronate-talc rich rock

Figure 4. Regional geology of the detailed study areas (modified after Bartlett et al. 1984). (Project S55.)

mafic minerals. The trend of the planar fabric is variable, ranging from 035° to 120° and the dip varies from 067° south to 060° north; however the dominant fabric trends 060° and dips near vertical. The foliation is locally deformed into small scale 'S' or 'Z' shaped folds.

Stretching lineations are defined by elongate amphiboles in the diorite and gabbro, by a mineral streaking in clastic metasediments and by elongate fragments within intermediate pyroclastic breccias. The lineation varies in plunge from 60° to 70° northwest at West Lake and East Lake, to 65° northwest at the Teal occurrence, to vertical at Discovery Lake and to 70° to 80° southwest along the North Caribou River.

Fault structures parallel or subparallel to the North Caribou River Fault were not observed within the Agutua Arm and South Rim Metavolcanic belts. The quartz-iron carbonate-sericite schist zone at the Agutua Arm property (Pyrotex showing) may, however, be hosted by such a structure.

IRON CARBONATE BEARING ZONES

Because of the lack of primary textures and structures within the quartz-iron carbonate zones in the map area, their protolith is not easily determined. However, at Discovery Lake, progressive destruction of primary textures, development of a planar foliation, and iron carbonate-sericite alteration within the tonalite have been documented. Similar observations have been made in the diorite at the Teal occurrence.

The origin of the quartz-iron carbonate-talc rich rock at Center Lake is also unresolved but because of the local high percentages of talc (50%) and because the unit is roughly stratigraphically equivalent to komatiitic flows exposed further north, it is suggested that this rock is an altered ultramafic. Some of the quartz-carbonate zones are clearly related to relatively late alteration events such as quartz-iron carbonate rich haloes which envelope quartz-ankerite veins cross-cutting massive mafic metavolcanics.

Isolated outcrops of quartz-iron carbonate-talc can be traced 3 km north of Center Lake and consistently flank the BIF which caps the quartz arenite-pelite metasedimentary sequence. The width of the carbonate zone is unknown to the north, but the eastern limit is approximately defined by a relatively unaltered sequence of mafic and komatiitic flows intercalated with and overlain by polymictic conglomerate exposed on the west shore of Eyapamikama Lake (Breaks *et al.* 1984). Within the altered zone, a single outcrop of chert-magnetite banded iron formation occurs which exhibits bedding striking 140° (Figure 4). The relationship of this iron formation to the main north-trending Keeyask Lake Belt is not known.

It appears that some of the carbonatization developed early in the geological history of the area, before the end of Keeyask Lake volcanism and sedimentation. This interpretation is based on the presence of carbonatized fragments within the relatively unaltered polymictic conglomerate which caps the Keeyask Lake section. Although economic concentrations of gold have not been discovered yet within the carbonatized zones, both the Pyrotex and Teal showings are hosted by these units. Quartz-sulphide vein samples obtained from the Teal Occurrence and the Pyrotex Showing, by the authors in 1985 assayed 32.5 ounces gold per ton and 1.3 ounces gold per ton respectively.

RECOMMENDATIONS

Although there are no reports of economic gold deposits in the North Caribou Lake Greenstone Belt, there are two locations within the study area which the authors consider to have the highest potential. These areas have several geological features that are common to gold deposits in the Abitibi and Wabigoon Greenstone Belts, including broad brittle-ductile deformation zones in a heterogeneous package of lithologies which have been carbonatized, silicified, sericitized and sulphidized. The two areas which show the best exploration potential are: within the North Caribou River Fault Zone and a zone (<50 m wide) north from the North Caribou River through Center Lake and through the area bounded by Eyapamikama Lake and Pakiagama Lake (Figure 4).

In most gold camps, particular lithological units or contact zones can be identified as being the most important for hosting gold mineralization within broader deformation zones. Within the area mapped during 1985, there has not been a particular lithological unit or contact zone of this nature identified which would greatly aid in exploration. Systematic lithogeochemical sampling of unaltered and altered rock types may help identify the key lithologies.

ACKNOWLEDGMENTS

We would like to thank H.W. Hodge (Moss Resources Limited) for permission to visit the Randall Lake and Agutua Arm properties, for providing us with valuable maps and data concerning the properties, and discussions concerning the geology of the belt. We are especially grateful to John North of Moss Resources for his hospitality while visiting their campsites, for his guided tour of the Center Lake property, and for providing valuable information and discussions on the geology of the Center Lake and Agutua Arms areas. We would also like to thank Northern Dynasty Exploration Limited (Eric Ewen, George Gorzynski, Bruce Youngman, and Dave Tupper) for describing to us the geology and mineralization of their properties in the Castor-Pollux Lakes region. Leo King of Sulpetro is thanked for allowing us access to the Teal property and for geological discussions of their properties.

Eric Dekemp and Fred Breaks of the Ontario Geological Survey (Precambrian Section) are thanked for guided tours of the Eyapamikama Lake and Opapimiskan Lake regions and for discussions covering the geology of the belt.

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Summary of Activities 1985, Operation Black River-Matheson (BRIM)

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This program is part of Operation Black River-Matheson (BRIM) which was funded equally by the Ontario Ministry of Northern Affairs and Mines and the Ministry of Natural Resources.

INTRODUCTION

Operation Black River-Matheson (BRIM) is a multi-year geoscience program which covers a 40 township block straddling Highway 101 east of Timmins (Night Hawk Lake) to the Ontario/Quebec border. The objectives of this program are to provide a comprehensive and integrated geoscience data base; to develop a regional stratigraphic and metallogenetic framework; and to promote new mineral exploration strategies and development in the BRIM area. These goals are being realized through the cooperation efforts of the Precambrian Geology, Engineering and Terrain Geology, Mineral Deposits and Geophysics/Geochemistry Sections of the Ontario Geological Survey and the Kirkland Lake and Timmins Resident Geologist Offices.

The BRIM area is part of the Superior Province of the Canadian Shield and is underlain by Early Precambrian (Archean) age metamorphosed supracrustal and plutonic rocks of the Abitibi Greenstone Belt. Middle Precambrian (Huronian) sedimentary rocks are locally present and unconformably overlie the Archean. These rocks occur within a topographic low and are mostly covered by thick clays of the Great Clay Belt. Consequently the surface relief of the BRIM area is typically a flat clay plain overlain by swampy organic terrain with minimal rock outcrop. Glacial sediments consisting of till, glaciofluvial deposits and widespread lacustrine clay occur in this basin. The overburden cover is thickest (+100 m in places) in the western half of the BRIM area with about 5% rock outcrop. The drift cover in the eastern BRIM portion is more variable with about 25% bedrock exposed.

The mineral potential of the BRIM area is high, major structural breaks such as the Destor-Porcupine and Pipestone Fault Zones, known to be associated with mineralization, cross this area. This high potential is yet to be realized because of the thick overburden cover and an inadequate geoscience data base. The BRIM program is an attempt to remedy this situation by undertaking baseline geological mapping, geophysical, geochemical, and mineral deposit studies to provide a comprehensive database which will encourage exploration and development.

The BRIM program was initiated in 1982 with Precambrian mapping and airborne geophysical surveys. Each year since then the program has been expanded to address specific problems and/or to take advantage of new opportunities. An explanation and summary of BRIM activities up to 1984 is given by Fortescue (1984). In 1985, the fourth year of the BRIM program, a wide range of geological programs are underway, these are described in the reports which follow this summary. The BRIM program at present (dependent on funding) is planned to continue for an additional 5 years until 1990. New components will continue to be added as current projects are completed or as the situation dictates. Geoscientific data for the BRIM area will be released throughout the course of this program and will culminate with major summary reports by 1990.

PRECAMBRIAN GEOLOGY

The Precambrian geology program initiated in 1982 involves detailed, synoptic, and stratigraphic mapping. These studies over the last four years have been focussed along the Destor-Porcupine Fault Zone in the west and central portions of the BRIM area. The 1982 program involved work in Stock, Taylor, Carr, Currie, Beatty, and Bowman Townships. In 1983, studies continued in Munroe, McCool, Hislop, Guibord, and Michaud Townships. The mapping of Beatty and Munro Townships and western McCool Township was completed in 1984. During the 1985 season the eastern half of McCool and northern portions of Hislop, Guibord and Michaud Townships were completed as outlined by Johnstone and Trowell (Project S56).

Publication of Precambrian Geology maps for Beatty, Munro and McCool Townships is expected by late 1985, additional publications for the remaining areas will follow. This data will be augmented by information collected in the eastern and southern portions of the BRIM area by the Precambrian Geology Section regular program to produce a synoptic compilation map for the entire BRIM area by late 1986.

Throughout the course of these Precambrian mapping activities, limited outcrop and widespread swampy terrain made data collection very difficult. Additional information about the bedrock geology in thick drift areas is being supplied via the overburden drilling program (Jensen *et al.* 1985).

QUATERNARY GEOLOGY

The Quaternary geology program was initiated in 1983 and involves two main components: detailed mapping and applied studies in aid of mineral exploration. The mapping component was undertaken first to determine the geological framework of the BRIM area. It involved establishing the surface distribution and thickness of the various glacial and postglacial deposits in the area, their stratigraphic and facies relationships and documenting their physical, chemical and engineering properties. Once this database is established applied studies using this information can commence.

Six Quaternary geology maps covering the entire BRIM study area are now published. They include the Ramore and Magusi River (NTS 42A/8 and 32D/5) map sheets by Baker *et al.* (1980, 1982) accompanied by a report (Baker 1985); the Lightning River and Matheson (NTS 32D/12 and 42A/9) areas by Vagners and Courtney (1985) and Vagners (1985); and the Porquis Junction and Watabeag River (NTS 42A/10,7) areas by Richard and McClenaghan (1985a,b).

Applied Quaternary geology studies in the BRIM area currently involve two programs: an overburden drilling, till sampling program started in 1984 in cooperation with the Geophysics and Geochemistry Section (discussed separately in a latter section) and an esker sampling program initiated in 1985. Esker sediments in addition to till have been shown to be effective reconnaissance exploration tool. The intent of this project is to evaluate the effectiveness of using the Munro Esker for this purpose. This project is described by Baker *et al.* (Project S57).

BRIM ECONOMIC GEOLOGIST PROGRAM

Initiated in 1984 and stationed at the Kirkland Lake Drill Core Storage Library the services of an economic geologist are available at the local level. Established and administered by the Kirkland Lake Resident Geologist's Office the objectives of this program are to promote exploration activity in the BRIM area by:

(1) assisting with assessment file searches and property visits;

(2) documenting new mineral occurrences and updating existing files;

(3) compiling data relevant to mineral exploration;

(4) helping "orient" new workers in the BRIM area.

A long term goal of this program is to compile a comprehensive, locally accessible database for the BRIM area.

A report of the Economic Geologist's activities and Geological Data Inventory Folio (GDIF) compilation status is given by Bath (Project S58).

MINERAL DEPOSITS

Detailed studies on the precious metal, base metal and industrial mineral potential of the BRIM area have been ongoing since 1984. The emphasis to date has been on gold and industrial mineral potential as described by Whittaker (Project S59), Malczak (Project S60), Troop (Project S61) and Malczak (Project S62) respectively.

The long term goals of this program are to develop a metallogenetic framework and to compile a comprehensive database with regard to stratigraphy, lithology, structure, alteration and metamorphism within the BRIM area.

GEOPHYSICS

Geophysical surveys are an integral part of the BRIM program. In 1982, the first year of the BRIM program, airborne magnetic and electromagnetic surveys were flown over the entire 40 township area (O.G.S. 1984). This work is described by Barlow and Pitcher (1984). The electromagnetic data, in addition to locating bedrock conductors and being a general mapping aid, is also providing information about the overburden cover.

Airborne data combined with ground geophysical techniques developed by Pitcher *et al.* (1984) and Barlow and Krentz (1984) are contributing to the success of the overburden drilling program by targeting buried bedrock valleys. Follow up work is allowing qualitative estimates of the overburden and bedrock topographic trends as described by Pitcher (Project S64).

OVERBURDEN DRILLING, TILL SAMPLING PROGRAM

Because the thick overburden cover in the BRIM area limits conventional exploration methods, a major focus has been to investigate the overburden to develop new and effective exploration strategies. The emphasis to date has been on combined exploration geochemistry/glacial geology methods undertaken jointly by the Engineering and Terrain Geology and Geophysics/Geochemistry Sections. Till was the prime glacial sediment type selected for this study because of its wide distribution, straight line transport, direct derivation from bedrock, ease of identification and known transport direction. In order to obtain till samples for geochemical analysis a combination of backhoe and sonic drilling techniques have been utilized and are described by Baker *et al.* (Project S63).

The overburden drilling, till sampling program was initiated in late 1984 and continued through 1985. The objectives are: to provide benchmark geological data regarding the stratigraphy, distribution, thickness, structure, mineralogy, and geochemistry of the glacial sediments with emphasis on till; and to develop new exploration strategies for the BRIM area. The drilling component of this program is also providing a better understanding of the underlying bedrock character (Jensen *et al.* 1985). Where possible the drillhole locations are positioned to obtain maximum information for the bedrock and mineral deposit studies which are being concurrently carried out as part of the overall BRIM Program.

Various airborne and ground geophysical techniques discussed previously used in conjunction with Quaternary and bedrock geology contribute in large part to the success of this program.

Preliminary information on the number and distribution of visible gold grains in sonic drill core samples was made available in late 1984 (Baker *et al.* 1984). Results of the bedrock core obtained from these borings was reported by Jensen *et al.* (1985). It is expected that the 1984 overburden core obtained from this program will be available for display at the Kirkland Lake Core Storage Library in late 1985. Full results of the 1984 drilling and backhoe till sampling are to be released by early 1986. Results of the 1985 work will be available by mid 1986.

SUMMARY

Operation Black River-Matheson (BRIM) is a multi-year integrated geoscience program initiated in 1982 and expected to continue until 1990. The purpose of this program is to promote mineral exploration and development in a 40 township area east of Timmins and north of Kirkland Lake. This is being accomplished by providing a comprehensive and integrated geoscience database on the bedrock and overburden geology, geophysical, geochemical, and mineral deposit characteristics within the BRIM area. These projects will provide valuable new information to those engaged in mineral exploration in this area. New exploration strategies developed as a result of this program can be applied to other areas of high mineral potential covered by thick overburden.

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S56. Precambrian Geology of the Black River-Matheson (BRIM) Area, District of Cochrane

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This project is part of Operation Black River-Matheson (BRIM) which was funded equally by the Ontario Ministry of Northern Affairs and Mines and the Ontario Ministry of Natural Resources.

INTRODUCTION

The field work completed during the 1985 field season represents the fourth year of a multi-year program to conduct detailed, synoptic and stratigraphic mapping along the Destor-Porcupine Fault Zone from east of Timmins to the Quebec border (Trowell 1982; Trowell and Johnstone 1983; Johnstone and Trowell 1984).

The areas mapped during 1985 include most of the eastern half of McCool Township and the northern halves of Hislop, Guibord, and Michaud Townships.

The four townships are located east of the Town of Matheson. They are accessible by Highway 101 running east from Matheson, by Highway 572 and concession roads in Hislop Township, and by lumber roads concentrated along the north-trending Munro esker which straddles the Munro/McCool and Guibord/Michaud Townships boundaries. Central and northeastern McCool Township is best accessed by helicopter.

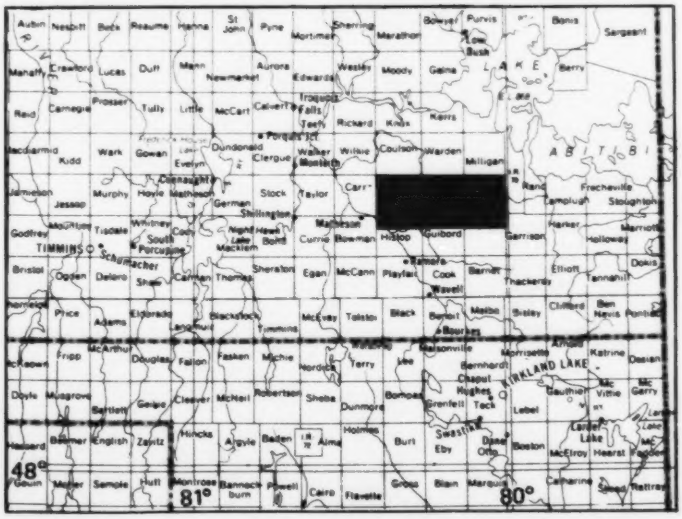
MINERAL EXPLORATION

Unless otherwise stated, the exploration information reported here was obtained from the Resident Geologist Files, Ontario Ministry of Northern Affairs and Mines, Kirkland Lake, or the Assessment Files Research Office (AFRO), Ontario Geological Survey, Toronto.

The record of mineral exploration in the Black River-Matheson area begins shortly after the turn of the century with the bulk of the exploration effort being directed towards gold. Over the years, exploration has been spurred on by the discovery of a large number of gold occurrences and the establishment of a few small mines including the high grade Croesus Mine (*see* report by Satterly 1952, also *see* Trowell and Johnstone 1983), in Munro Township. Today the only gold mine still operating east of Matheson is the Ross Mine in southeast Hislop Township. A gold prospect owned by Maude Lake Gold Mines Limited in northwest Beatty Township has had extensive exploration work done on it and is being presently evaluated for its gold potential.

In the past, two massive sulphide (copper, zinc) mines (Potter Mine and Potterdoal Mines, Trowell and Johnstone 1983) and an asbestos mine (Munro Mine, Trowell and Johnstone 1983) operated in Munro Township. An asbestos mine (Hedman Mine) located at the southern edge of Warden Township, still maintains limited production. Of these two types of deposits, most of the exploration effort was directed towards asbestos, particularly during the 1950s and 1960s. Magnetometer surveys and diamond drilling programs designed to delineate and explore favourable ultramafic intrusions were extended into McCool Township during this period, but there has been no further work of this nature done in recent times.

Exploration programs conducted in the four townships usually involved magnetic and electromagnetic surveys with follow-up diamond drilling of anomalies,


Aubin
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Beck
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St John
Pyne
Mortimer
Sherring
Marathon
Bowyer
Purvis
Low Bush
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Sargeant
Mahaffy
Crawford
Lucas
Duff
Mann
Newmarket
Aurora
Edwards
Wesley
Moody
Galna
LAKE
Berry
Reid
Carnegie
Prosser
Tully
Little
McCart
Calvert
Iroquois Falls
Teefy
Richard
Knox
Kerrs
Macdiarmid
Kidd
Wark
Gowan
Evelyn
Dundonald
Clergue
Porquis Jct.
Walker
Wilkie
Coulson
Warden
Milligan
ABITIBI
Jamieson
Jessop
Murphy
Hoyle
Connaught
Matheson
German
Stock
Taylor
Carr
Rand
Frecheville
Lamplugh
Stoughton
Godfrey
Mountjoy
Tisdale
Whitney
South Porcupine
Cody
Shillington
Night Hawk Lake
Bond
Currie
Matheson
Bowman
Hislop
Guibord
Garrison
Harker
Holloway
Marriott
TIMMINS
Schumacher
Mackiem
Bristol
Ogden
Deloro
Shaw
Carman
Thomas
Sheraton
Egan
McCann
Playfair
Ramore
Cook
Barnet
Thackeray
Elliott
Tannahill
Dokis
Wavell
Price
Adams
Eldorado
Langmuir
Blackstock
Timmins
McEvay
Tolstoi
Black
Benoit
Bourkes
Maisbo
Bisley
Clifford
Ben Nevis
Pontiac
Fripp
McArthur
Douglas
Fallon
Fasken
Michie
Nordica
Terry
Lee
Larsonville
Morrisette
Arnold
Katrine
Ossian
KIRKLAND LAKE
Bernhardt
Chaput Hughes
Doyle
Musgrove
Bartlett
Geikie
Cleaver
McNeil
Robertson
Sheba
Dunmore
Bompas
Grenfell
Teck
Lebel
Gauthier
Mc Vittie
Mc Garry
Hincks
Argyle
Baden
Alma
Holmes
Burt
Swastika
Eby
Dane
Otto
Boston
Larder Lake
McElroy
Hearst
McFadden
48°
Gouin
Mercer
Semple
Hutt
Montrose
81°
Bannockburn
Powell
Cairo
Flavelle
Gross
Blain
Marquis
80°
Catharine
Skead
Rattray

LOCATION MAP   Scale : 1 : 1 548 000 or 1 inch to 25 miles

but more recently this initial stage has also included overburden drilling and sampling, biogeochemical surveys, and ground water sampling.

Although most of the exploration has been directed towards the search for gold-bearing quartz and quartz-carbonate veins in the vicinity of the Destor-Porcupine Fault Zone and its related splays, reports of old mining properties in Hislop Township (Prest 1956) indicate that zones of carbonatized and/or hematized country rock and feldspar porphyry intrusions may also host economic gold mineralization as disseminated native gold or within pyrite. Associated ore minerals may include pyrite, chalcopyrite, arsenopyrite, galena, and silver.

At present the most active gold property (Belore) is located in southern McCool Township where Placer Development Limited has followed-up geophysical surveys (magnetometer, electromagnetic-VLF) with more than 25 diamond-drill holes totaling more than 17 000 feet (5187 m) being drilled as of the fall of 1984. Noranda Mines Limited and Cominco Limited have also taken an interest in the area, the former acquiring land to the north of the Belore property and the latter expanding its claim group into northern Guibord Township. Diamond drilling has also been conducted within the last two years by Pamour Porcupine Mines Limited in northern Hislop Township.

Placer gold can be found within the Munro esker but concentrations rich enough to warrant a profitable mining operation have yet to be found.

GENERAL GEOLOGY

AREA 1: NORTHERN HISLOP AND GUIBORD TOWNSHIPS AREA

Three of the four townships have been the subject of Ontario Government reports; Hislop Township (Prest 1956), Guibord Township (Prest 1951), Michaud Township (Satterly 1948), and McCool Township (Satterly 1953).

Apart from a single Abitibi Dike Swarm (Keweenawan) diabase dike which passes unexposed through the northwestern corner of Hislop Township, all of the volcanic and sedimentary rocks underlying the four townships are of Early Precambrian (Archean) age (Figure 1). The felsic rocks of the Hunter Mine Group in nearby Rand Township have yielded a U-Pb zircon date of 2710 ± 2 Ma (Nunes and Jensen 1980). Stratigraphic terminology follows that of Jensen and Langford (1983).

Rock exposure is limited in the area comprising northern Hislop, Guibord, and Michaud Townships and this allows for only an incomplete understanding of stratigraphy and structure. Based on the mapping of scattered outcrops, diamond-drill hole data, and aeromagnetic survey interpretation, the area appears to mark the southern extent of komatiitic and tholeiitic rocks belonging to the Stoughton-Roquemaure Group. This group which disconformably overlies the calc-alkalic Hunter Mine Group and is overlain by the tholeiitic Kenojevis Group, is the lowermost group of a second cycle of volcanism recognized on the northern limb of the Blake River Synclinorium (Jensen and Langford 1983). The Blake River Synclinorium is a large east-trending structure bordered in the Kirkland Lake area by the Lake Abitibi and Round Lake Batholiths to the north and south, respectively. The limbs of the synclinorium are disrupted by the two east-trending Destor-Porcupine and Larder Lake-Kirkland Lake Fault Zones. The Destor-Porcupine Fault Zone trends at approximately 120° through northeast Hislop Township before trending east at the township border and then southeast into the southeastern corner of Guibord Township. In the southern halves of Guibord and Michaud Townships, the fault zone is characterized by a narrow fault-bounded band of Timiskaming group sediments, a younger graben-fill deposit.

North of the fault zone underlying the northeastern corner of Hislop Township and most of northwest Guibord Township are found the wackes, feldspathic arenites, and argillites of the Porcupine Group. North-central Guibord Township marks the eastern termination of the Porcupine Group which extends westward to the Timmins area. Weathering lower than the surrounding volcanic rocks, the sedimentary sequence is largely unexposed, buried beneath a deep overburden cover. The few exposures are along the belt's northern and southern contacts. Where exposed in Beatty and Munro Townships, the northern contact is disconformable, marked by a steeply dipping fault, but upon entering Guibord Township the contact is conformable. The southern contact appears to be conformable with the Kenojevis Group (Prest 1951) based on borehole data at the Hislop/Guibord Townships border but a fault contact is indicated to the northwest in Beatty Township.

The sediments are medial to distal turbidites largely represented by massive quartz or feldspathic arenites deposited in thick beds or more commonly thin beds interbedded with argillite. Arkose is mentioned in earlier reports (Prest 1951, 1956), but it appears that at least some of these reddish coloured rocks may be hematized feldspar-rich sandstones. The sandstones tend to be rich in quartz and plagioclase feldspar. A pebble conglomerate unit located at the old Talisman property in north-central Guibord Township was found to contain rhyolite clasts. These features combined with the fact that the northern contact zone possesses felsic tuff horizons (Johnstone and Trowell 1984) indicates a calc-alkalic volcanic provenance as suggested by Jensen and Langford (1983).

Although the sediments were probably largely derived from Hunter Mine Group volcanic rocks, the stratigraphic position of the assemblage, at least in this area, appears to be towards the base of the Stoughton-Roquemaure Group. Two small lenses of argillaceous sediment located south of the southern contact in Hislop and Guibord Townships further indicate that the sediments interfinger with the Stoughton-Roquemaure volcanic rocks at this end of the belt.

The faulted contact between the volcanic rocks and the sediments is characterized by a lens of intense carbonatization containing quartz-carbonate veins and small patches of relatively unaltered sedimentary rock. The green, fuchsite-rich carbonate has replaced some of the volcanic rocks, but it appears to have been largely the result of carbonatization of sediments. Narrow zones of carbonatization also extend into the sediments along cross faults. The sediments have also been affected in places by sericitization.

The north-facing volcanic assemblage exposed north of the sedimentary belt consists of 1200 to 1300 m of tholeiitic lavas overlain by the base of a komatiitic sequence which is approximately 1000 m thick where it straddles the Munro-Guibord Townships boundary. Most of the underlying sequence consists of iron-rich tholeiitic basalt as massive and pillowed flows and flow breccia units. Variolitic flows can be found throughout but the largest concentration is found at the base of the sequence. At the contact between the two groups of volcanic rocks, two thin sills of peridotite and pyroxenite intrude thick flows of massive magnesium-rich tholeiitic basalt. Here the komatiite succession begins with a thick ponded ultramafic flow overlain by several 4 to 8 m thick flows of peridotitic komatiite. All of the flows display coarse olivine spinifex zones. The komatiitic sequence found farther east along strike begins with flows of basaltic komatiitic composition.

The only other komatiite flows found in the area are located in southern Guibord Township (L. Jensen, Geologist, Ontario Geological Survey, personal communication, 1985) and in the Kelore Mine area in east-central Hislop Township.

The volcanic rocks found south of the sedimentary belt have been intruded by a number of sill-like bodies of gabbroic or dioritic composition. Two notable exposures occur at 'Froome Hill' in Hislop Township and at 'Guibord Hill' towards the centre of Guibord Township. The gabbro body at 'Froome Hill' consists of a series of irregular finger-like bodies of gabbro oriented parallel to the stratigraphy but also to the Destor-Porcupine Fault Zone which trends at 140° to 110° along the side of the main outcrop group. The gabbro body contains within it a string of thin breccia lenses oriented roughly parallel to the intrusive contact but at two points trending into the contact. The breccia is not unlike the flow top breccias found in the surrounding country rock and may represent large xenoliths picked up by a separate pulse of the intrusion. It is also possible that magma of the same composition carrying fragments of fine grained gabbro and country rock intruded fractures opened up in the cooling gabbro body.

A true intrusive breccia is exposed on 'Guibord' Hill within a diorite/gabbro intrusive complex. Composed primarily of fine to medium grained fragments of diorite or gabbro in a fine to coarse grained matrix of the same composition, this rusty weathering, pyrite-rich breccia occupies almost half of the exposed intrusion. There is also a dike, branching off the complex to the west, which contains irregular masses of intrusive breccia but the breccia here is composed of mafic lava fragments. The complex intruded along the southern contact of the sedimentary belt and was interpreted to be a small stock or plug intruded in turn by a second, later, diorite plug or boss and dikes (Prest 1951). The 'Froome Hill' intrusions are similar and may in fact not be sills, but large fracture fillings where mafic magma intruded up faults oriented subparallel to bedding planes that are related to the Destor-Porcupine Fault Zone.

Thin sill-like bodies of syenite, feldspar porphyry syenite, quartz porphyry and quartz and feldspar porphyry were interpreted to be present from mine workings, outcrop and mainly borehole data in the Kelore Mine area and west of 'Froome Hill' (Prest 1956). A summary of the Kelore Mine geology describes bodies of chloritic and felsitic carbonatized tectonic breccia intruded in places by felsic dikes (Prest 1956). Borehole data indicates a large number of syenite bodies and alteration zones including carbonatization, silicification, hematization, and syenitization. Much of the rock close to the Destor-Porcupine Fault Zone in both townships shows a reddish colouration due to hematization. The 'syenitization' referred to by Prest (1956) may be more this form of alteration rather than that of alkali enrichment. The reddening of feldspar porphyry intrusive rocks and massive flows may have been misinterpreted in some cases as potassic metasomatism rather than hematization. The Kelore Mine area is situated close to bands of felsic volcanic rocks, flows, tuffs, and tuff-breccias which can be found within the middle of northern Hislop Township, through the Ross Mine area into southeast Guibord Township. These felsic rocks only outcrop at two locations in northern Hislop Township on the Pike River. One outcrop shows a white-weathering massive feldspar porphyry probably a rhyolite flow, and what appears to be a flow breccia. A pyroclastic breccia unit is exposed nearby to the west. Here fragments of feldspar porphyry ranging in size from a few centimetres to a metre along with a small number of mafic volcanic and pumice fragments are enclosed within a dark green crystal tuff matrix. These felsic bands are thought to belong to a marker horizon of felsic volcanic rocks and iron formation found at the top of the Stoughton-Roquemaure Group (Jensen and Langford 1983).

In addition to the mafic intrusions, borehole and geophysical data indicate that there is a large lensoid peridotite body west of 'Froome Hill'. Such intrusions are also found in the Beatty Township area, particularly along major strike faults.

In the eastern part of the area, a small number of scattered outcrops indicate the presence of two large felsic stocks; a granite stock 3 to 4 km across in southeast Guibord Township, and a syenitic feldspar porphyry intrusion of similar size to the north, also in Guibord Township. A smaller stock of porphyritic syenite is found 2 km east of 'Guibord Hill' and a small lensoid body of granitic feldspar porphyry dipping 60° south (Prest 1951) intrudes the Destor-Porcupine Fault Zone immediately south of 'Guibord Hill'.

Other intrusions found throughout the region include lamprophyre dikes and north-trending Matachewan diabase dikes.

Structural Geology

The regional stratigraphy dips steeply and generally trends 95° to 110°. The Destor-Porcupine Fault Zone, characterized by subvertical shearing and tight isoclinal folding between it and the Hislop Fault, marks a major change in facing direction. Apart from the possibility of some minor folding within the sedimentary belt, indicated in some limited diamond-drill hole data, the stratigraphy north of the fault zone faces north and the rocks to the south of the fault zone mark the beginning of a major south-facing monoclinal succession. To the north, major folding is not encountered until the centre of Munro Township is reached.

The Destor-Porcupine Fault Zone at the edge of 'Froome Hill' consists of several parallel, near-vertical faults over a zone 200 to 300 m wide. The country rock has taken up far more of the deformation associated with the zone than the gabbro/diorite intrusions and displays a schistosity which extends for at least 400 m out from the fault zone to the eastern extent of the outcrop group. It has been suggested by Jensen and Langford (1983) and others that the fault zone has been active over a long time period even during the eruption of the Stoughton-Roquemaure lavas. It is possible that the mafic intrusions of 'Froome Hill' intruded up fractures opened by the fault system after the stratigraphy had been rotated to a near-vertical position due to basin subsidence to the south. With a relatively more competent rock sealing the early faults, the fault zone may have then migrated north.

This tendency for fault splays and shearing related to the Destor-Porcupine Fault Zone to follow weaker lithological units such as interflow sediments and carbonatized ultramafic rocks can be seen in Beatty, Munro, and McCool Townships. One of these splays, the Munro Fault Zone, is entirely enclosed within a komatiite flow unit in Munro Township, a part of the same komatiitic sequence that passes into northeastern Guibord Township. The sense of displacement of the Munro Fault Zone and the Contact Fault (Satterly 1952) between the sediments and the northern volcanic rocks was largely vertical and the magnitude of relative movement is uncertain but likely minor relative to the main break. Other late-stage shearing has taken place at the eastern side of Guibord Township along the contact between the volcanic rocks and the syenite stock. The senses of displacement for all the strike faults are uncertain.

A few major cross faults which possess horizontal displacements that are much greater than that found in Beatty, Munro, and McCool Townships are present in Hislop, Guibord, and Michaud Townships. There is no evidence to suggest that these faults displace the Destor-Porcupine Fault Zone and it is probable that they were generated while the zone was still active. All of these faults have been interpreted from magnetometer surveys and from some borehole data (Prest 1951, 1956). North of the Destor-Porcupine Fault Zone on both sides of the Munro-Guibord Township line there is a series of north-northeast to northeast-trending, dextral sense faults displaying horizontal displacements of <200 m. These may be related to two major faults indicated by Prest (1951) in north-central and northeast Guibord Township.

A major northwest to north-northwest striking fault, the Hislop Fault, runs from a point on the Destor-Porcupine Fault Zone in southwest Beatty Township, down through Hislop Township and southward towards the centre of the Blake River Synclinorium. Aeromagnetic data indicate an apparent sinistral-sense displacement of almost 3 km, but a vertical component of movement, possibly more significant, is indicated by the localization of a gently-dipping assemblage of Timiskaming Group sediments on the eastern side of the fault in the southeastern corner of Hislop Township.

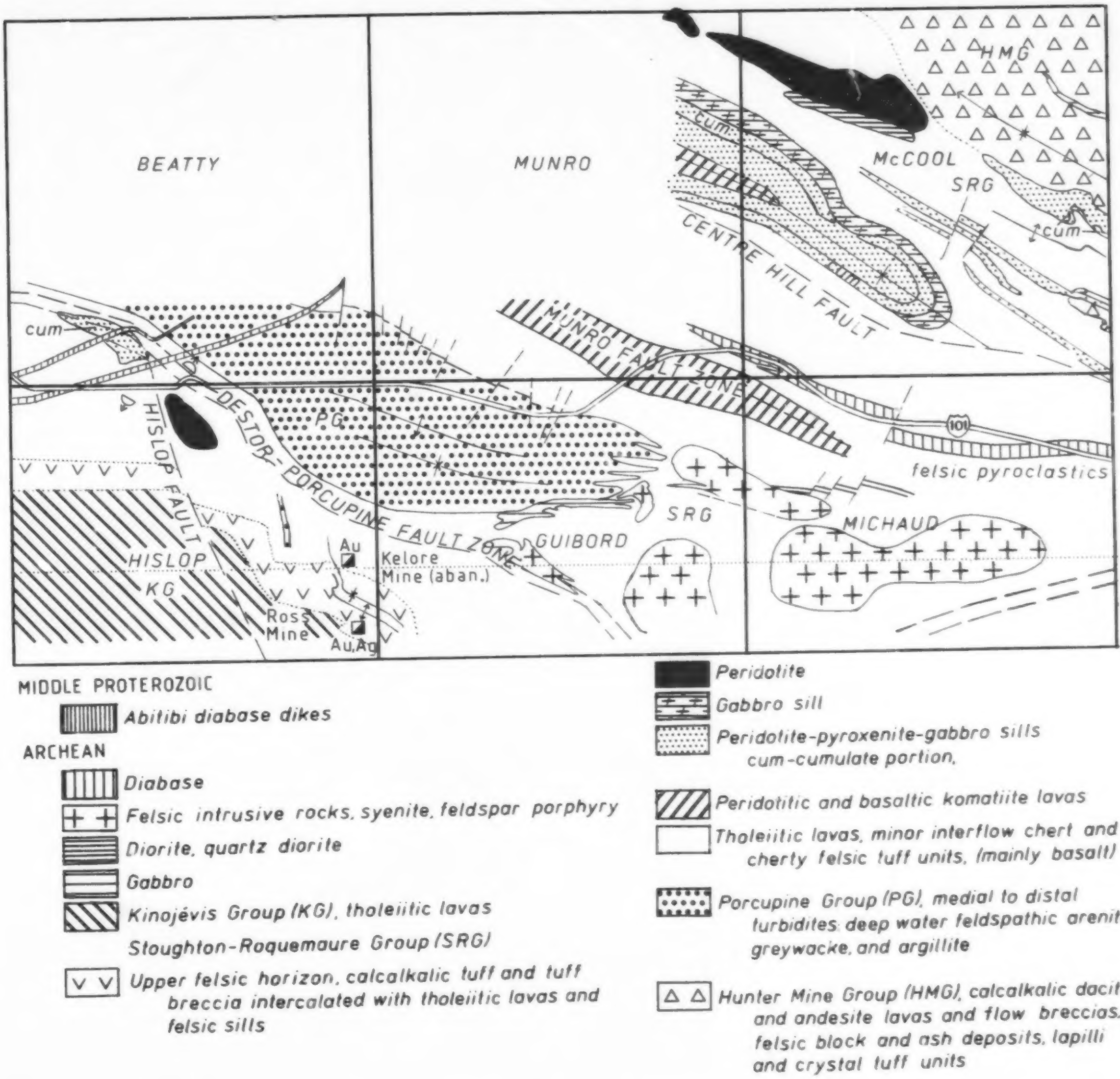
AREA 2: NORTHERN MICHAUD AND EASTERN McCOOL TOWNSHIPS AREA

These areas (Figure 1) are largely underlain by a succession of tholeiitic lavas, flow breccias, and minor fine grained interflow sediments, there is also a thin band of rhyolite flows located south of Perry Lake in northwest Michaud Township and an area of massive and pillowed flows of basaltic komatiite intercalated with tholeiitic lavas found west of this lake. These latter flows probably mark the extension of the komatiite unit found along the Munro Fault Zone.

McCool Township is the more important of the two areas because it shows the transition between the calc-alkalic andesites, dacites, and rhyolites of the Hunter Mine Group and the overlying andesites and basalts of the Stoughton-Roquemaure Group. Based on a limited number of exposures, the main contact between the two groups trends at approximately 110° through the northeastern part of the township and then it runs in a northwest direction crossing the northern border. An angular discontinuity may be present between these two groups.

The stratigraphic record exposed in the township indicates that Hunter Mine Group volcanism continued for a while after the onset of Stoughton-Roquemaure volcanism reflected in the rapid outpouring of subaqueous mafic and ultramafic lavas on the flanks of a calc-alkalic volcanic complex. One such complex may have been located to the east in Rand Township (Jensen and Langford 1983). A small, circular felsic porphyry complex is located there and the tholeiitic lavas in the southeastern corner of McCool Township and the adjacent Indian Reservation interfinger with calc-alkalic lavas and pyroclastic rocks in that direction. A major centre for the Hunter Mine Group may have also existed in the Lake Abitibi area in a location now occupied by the Lake Abitibi Batholith (Jensen and Langford 1983).

A facies change occurs at the contact between the Hunter Mine and Stoughton-Roquemaure Groups in the map area. North of the contact there is mainly a succession of flows and flow breccias, along the contact zone there are primarily deposits of crystal tuff, lapilli-tuff and tuff-breccia, and above the contact thin interflow units of cherty tuff, chert, and fine argillaceous sediment can be found. These latter waterlain tuff layers are usually rich in pyrite and commonly display soft-sediment deformation features. Interpreted to be a more distal type deposit, they can be found high in the McCool Township stratigraphy. Also noteworthy is a breccia unit exposed just above the contact which incorporates fragments from both groups. The rhyolite blocks present in this unit may represent blocks that may have


BEATTY
MUNRO
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cum
CENTRE HILL FAULT
MUNRO FAULT ZONE
DESTOR-PORCUPINE FAULT ZONE
HISLOP FAULT
PG
101
felsic pyroclastics
SRG
MICHAUD
GUIBORD
HISLOP
KG
Au
Kelore Mine (aban.)
Ross Mine
Au,Ag
MIDDLE PROTEROZOIC
Abitibi diabase dikes
ARCHEAN
Diabase
Felsic intrusive rocks, syenite, feldspar porphyry
Diorite, quartz diorite
Gabbro
Kinojévis Group (KG), tholeiitic lavas
Stoughton-Roquemaure Group (SRG)
Upper felsic horizon, calcalkalic tuff and tuff breccia intercalated with tholeiitic lavas and felsic sills
Peridotite
Gabbro sill
Peridotite-pyroxenite-gabbro sills cum-cumulate portion.
Peridotitic and basaltic komatiite lavas
Tholeiitic lavas, minor interflow chert and cherty felsic tuff units, (mainly basalt)
Porcupine Group (PG), medial to distal turbidites: deep water feldspathic arenite, greywacke, and argillite
Hunter Mine Group (HMG), calcalkalic dacite and andesite lavas and flow breccias, felsic block and ash deposits, lapilli and crystal tuff units

Figure 1. *Generalized geology of the areas mapped within Hislop, Guibord, Michaud, and McCool Townships.*

rolled off the rubble slope of a calc-alkalic volcano or dropped into the flow breccia during a period of explosive activity.

The contact zone in McCool Township has been intruded by a variety of intrusions. Intrusive relationships were difficult to determine but it appears that an edge of the contact zone to the west has been intruded by a large lensoid peridotite body bordered on one and possibly two sides by a younger two-phase diorite intrusion, an early diorite body intruded by a later quartz diorite. To the east, the area immediately south of the contact zone is underlain by either a 800 to 1000 m thick peridotite-gabbro sill or a thinner sill with a discordant gabbro. At least two peridotite/pyroxenite sills, 200 to 400 m thick trend through the centre and southeastern corner of the township. Only one of these is clearly exposed where it has intruded pillowed mafic flows and, at the southeastern end, a tongue of felsic rock. Crystal setting was uneven in this body as evidenced by a discontinuous cumulate layer.

The largest intrusion in the area is found exposed at 'McCool Hill' in the south-central part of the township. Here a 600 to 800 m thick peridotite-pyroxenite-gabbro sill, underlain by a smaller gabbro sill, wraps around the nose of a major syncline which extends northwest through the centre of Munro Township. The layered sill is found on both limbs of the fold while the gabbro sill begins at the nose of the fold and extends back only on the northern limb. The northern limb also exhibits a short break in the cumulate of the larger sill.

A medium grained diabase dike, approximately 400 m wide and trending between 100° and 120°, outcrops along Highway 101 in both townships. In the southwestern corner of McCool Township, a sliver of country rock exposed in a outcrop group south of the highway suggests that the body either divides or widens at that point. The intrusion carries xenoliths of country rock. It is possible that it has intruded a strike fault that begins in southern Munro Township.

Michaud Township has at least two large felsic stocks which extend across the middle of the township as elongate pods. One is the extension of the porphyritic syenite body in eastern Guibord Township and the other, possibly two separate pods, is a porphyritic granite.

Structural Geology

The stratigraphy in both townships dips steeply and generally trends 100° to 120°. The strata face north until they meet the axis of the McCool Hill Syncline in southeast McCool Township. It is then folded about two shallow isoclinal folds whose synclinal and anticlinal axes terminate in the centre of the township. The rest of the stratigraphy in the northern half of the township faces south.

Although evidence is lacking in the areas situated between outcrop ridges, the area is broken up by a series of strike faults. Although it is assumed that much of the motion associated with these faults is vertical, two faults do have significant sinistral-sense displacements. One fault caused drag folding in a sill on the eastern side of McCool Township and another fault, the Centre Hill Fault (Satterly 1952), caused a displacement of over 3 km of the McCool Hill synclinal axis.

Minor northeast-trending cross faults occur throughout the area. Most of these faults involve apparent horizontal displacements of <400 m.

ECONOMIC GEOLOGY

For the area covered by this report, the mineral potential likely lies with gold and, to a lesser degree, base metal exploration. The region has all the elements of a gold area; nearby past, present, and possibly future producing mines, the Destor-Porcupine Fault Zone, carbonatized ultramafic rocks, pyrite-rich graphitic sediments, and late stage felsic intrusions. To understand and explore for gold mineralization in the area it is necessary to first of all gain an understanding of the nature of fracturing and deformation along the Destor-Porcupine Fault Zone and its related splays and then to identify fracture systems that were active when gold-bearing fluids were travelling up the Destor-Porcupine Fault Zone. The potential lies in the overburden covered valleys between outcrop bands which are occupied by fault zones (such as the Munro Fault Zone) that developed due to motions along the main Destor-Porcupine Fault Zone. Exploration in such areas is expensive but with improved magnetometer surveys, more overburden drilling data and a greater attempt made to understand the structural geology of the area, such projects will gradually become more viable. Other possible exploration targets are the pods of intense carbonatization such as are found south of 'Guibord Hill' along the Destor-Porcupine Fault Zone and at points along the Contact Fault.

Although not as sought after, base metal exploration does have some potential along the contact between the Hunter Mine Group and the Stoughton-Roquemaure Group. Two copper-lead-zinc deposits did exist in Munro Township and the cherty interflow sediments and various breccia units common in the area, do show a general enrichment in sulphide minerals, usually pyrite and pyrrhotite. This relatively more permeable transition zone between the two volcanic groups should not be overlooked as a gold exploration target also.

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S57. Reconnaissance Heavy Mineral and Geochemical Sampling of the Munro Esker, Lake Abitibi Area, Cochrane District

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This project is part of Operation Black River-Matheson (BRIM) which was funded equally by the Ontario Ministry of Northern Affairs and Mines and the Ontario Ministry of Natural Resources.

INTRODUCTION

Quaternary geology studies carried out in the third year of the Black River-Matheson geoscientific program centred on the backhoe sampling of the Munro Esker, east of Matheson, Ontario. Sampling took place in an eight township corridor which straddles the esker from Michaud Township in the south to Kerr Township in the north (Location Map).

Highway 101 bisects the study area in an east-west direction. Access along and across the esker is by lumber and exploration roads and trails. South of the highway these are highly developed while north of the highway few roads presently exist but numerous lumber roads are under construction.

PROJECT AIMS

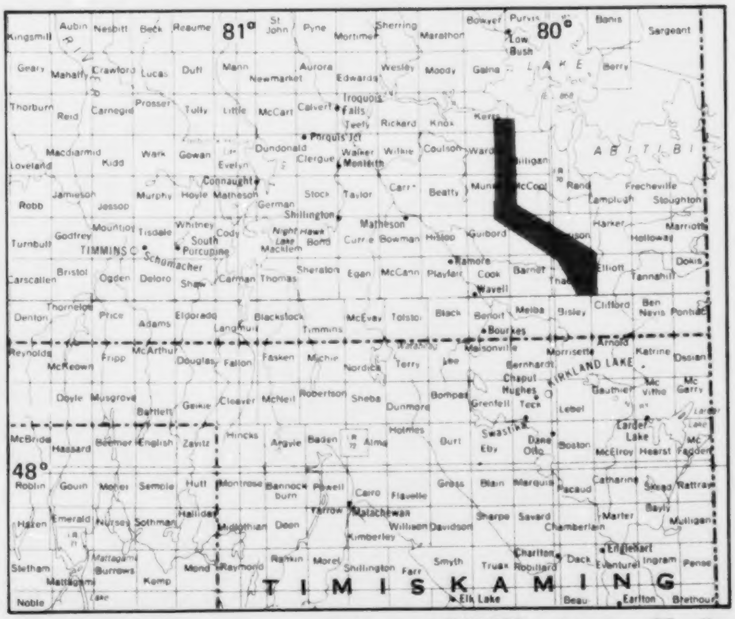
The purpose of this research project is multifold:

1. to evaluate whether the Munro Esker is an effective indicator of mineralization in the area it traverses;
2. to assess which minerals are present and in what concentrations in the near surface zone of the esker;
3. to sample various depositional environments within the esker;
4. to determine the effects of redeposition on mineral concentrations;
5. to compare the mineralogy and geochemistry of the esker samples with till samples taken adjacent to the sample corridor.

The rationale for establishing these aims is based on the present state of geological knowledge and the need to understand the Quaternary geology of the region. Once this is accomplished effective exploration programs can be carried out in areas of glaciofluvial cover.

REGIONAL GEOLOGICAL BACKGROUND

The Munro Esker traverses two major east-west trending fault systems, the Destor-Porcupine and the Pipestone (Figure 1). Drilling and sampling suggests that gold occurrences are concentrated along these features. In addition, assessment work indicates that the gold potential of the rocks flanking the esker is high. It is therefore likely, that some scattered zones of mineralization are present along the length of the study area.



LOCATION MAP

Scale : 1 : 1 548 000 or 1 inch to 25 miles

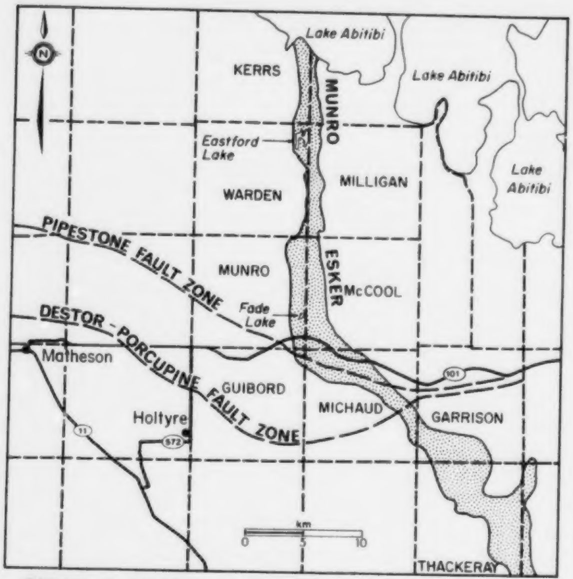


Figure 1. *Outline of the Munro Esker in the study area. (Project S57.)*

Exploration sampling of the esker has previously shown that significant numbers of gold grains occur in the Eastford Lake area, Warden and Milligan Townships (Ferguson and Freeman 1978). This ground is presently being assessed as a potential placer gold source. A placer operation located at the southern end of Fade Lake, Munro Township was in intermittent operation for two years before closing down in 1983.

Previous mapping and sampling work on the Munro Esker to the south, east of Kirkland Lake (Baker 1981, 1985), has shown the presence of three major depositional environments. The most distinctive, the crest, was deposited in a narrow conduit or tunnel extending back from the ice front. Morphologically the crest is a linear, bell shaped ridge occurring in segments of 1 to 3 km in length. The second depositional environment is termed the ice-walled channel. Subaerial deposition took place in a broad ice-walled re-entrant in the glacier margin, most commonly, by braided streams. The third depositional setting is deltaic and is defined to include material deposited at the sediment-lake interface. This includes both subaqueous fans and Gilbert type deltas.

Material deposited at or below the highest level of the glacial lake fronting the ice was subject to reworking by wave and current actions as the lake receded. The reworked sediments are now present in the form of beaches, bars and glaciolacustrine sand plains. It is possible that washing and winnowing served to concentrate economic minerals in some of these features.

SITE SELECTION

The outline and position of the Munro Esker was defined by the Quaternary mapping of the sample corridor (Baker *et al.* 1982, Vagners 1985). The type and extent of the depositional environments for this portion of the esker were determined through air-photo interpretation and ground checks. Sample locations were selected and field checked prior to sampling equipment being contracted.

Sites were positioned on the three depositional environments and on glaciolacustrine features such as beaches and bars. The number of sites located on the various environments or features were approximately proportional to the areal (surficial) extent of the particular deposits. Eolian dune deposits were avoided in sampling unless they were thin and could be trenched through.

EQUIPMENT

A rubber tired backhoe/loader was selected for use on this project. The advantages of this equipment are: (1) it is capable of digging a 5 m trench or clearing a 6 m face in a short period of time; (2) it has a high degree of maneuverability at a site; (3) it moves quickly between sample sites under its own power; and (4) it is a relatively cost effective means of obtaining a bulk sample.

The equipment used on this project were a Case® 580C and a John Deere® 410 backhoe/loader. Both had an extendahoe option to allow for increased reach of the bucket. A total of 96 trenches were dug in 132 hours of equipment time. On average a trench could be dug, notes made, a sample taken and the pit backfilled in approximately an hour to an hour and a half.

FIELD OPERATIONS

At each sample site, a 2 to 3 m deep trench was dug to expose the esker material. Although the equipment was capable of excavating to greater depths, the loose nature of the sediments made entering a deeper pit unsafe. Once the trench was opened the stratigraphy was examined and sedimentological details recorded on a data sheet. A sample interval, usually near the base of the pit, was selected and detailed notes on that interval recorded. These include information on any structures, bedding, and oxidization or weathering. Notes were also taken on the texture of the matrix, its sorting, and grain angularity. In addition, clast content, size, and angularity were recorded.

At each site, an 8 to 10 kg sample of -4 mesh (-4 mm) material was collected. If the sample interval contained +4 mesh material it was sieved at the site. When sieving was complete the +4 mesh material containing pebbles large enough to be identified was retained for future examination.

Two samples each approximately 250 g were also collected. One is to be sent for size analysis with selected samples undergoing Chittick analysis for carbonate content determinations. The second 250 g sample was collected for whole rock analysis on the -10 mesh (-2 mm) fraction.

SAMPLE PREPARATION

The 8-10 kg bulk samples are to be sent for heavy mineral separation, a process that involves:

1. wet sieving the sample to -10 mesh (-2 mm);
2. passing the -10 mesh over a shaker table to separate the majority of the light minerals from the heavies;
3. refining and cleaning the heavy minerals by a heavy liquid separation designed to "float off" the material with a specific gravity <3.3;
4. removal of the magnetics from the ≥3.3 specific gravity heavies.

Because of the high specific gravity of gold it separates easily from the other minerals on the shaker table and takes up a different position of travel across the table. These factors allow gold grain counts to be made at this stage of the processing. Should large numbers of gold grains be present, the heavy minerals can be panned to make sure none of the gold grains were missed during tabling. Following separation, the gold grains can be examined microscopically to determine size, shape, and surface characteristics that may yield clues to the history of their transport and deposition. After examination the grains are returned to the heavy mineral concentrates.

At this point in the processing the heavies can be examined under a binocular microscope. Estimates of the various minerals present can be made and economically important minerals, or minerals indicating economic mineralization, identified.

GEOCHEMICAL ANALYSIS

The non-magnetic ≥3.3 specific gravity heavy mineral concentrates are to be analyzed for gold by Neutron Activition Analyses (NAA). The Ontario Geological Survey has elected to have the entire concentrate analyzed in an attempt to eliminate the "nugget effect" caused by analyzing small samples or sample splits. Following NAA the heavies are split, with half (or 10 g, whichever is greater) to be analyzed for a suite of trace elements by wet geochemical methods. The remaining heavies are to be stored for future reference and study.

In addition esker samples are to have the "total sample" -10 mesh material analyzed for a suite of trace elements and whole rock geochemistry.

EXPECTED APPLICATION OF RESULTS OF ESKER SAMPLING PROGRAM

Mineralogical and geochemical analysis of the 96 samples are expected to be completed by the Spring of 1986. This data will be used to augment previous results from samples taken further south along the esker.

The results of this sampling program are expected to be useful in several ways:

1. They will serve as an evaluation of the effectiveness of esker sampling in the Abitibi region and determine whether esker sampling can be used as a reconnaissance exploration tool.
2. Examination of both the pebble and sand fractions of the samples will determine the percentage of local and distal material. Particular attention will be paid to discern differences between deposition environments, thus allowing a ranking system to be established for their relative use in exploration.
3. Detailed mineralogical work should also determine whether the kimberlite indicator minerals, pyrope garnet and chrome diopside, are present in this portion of the esker. Should the minerals be identified then the potential area in which kimberlite bodies may exist will be considerably expanded. These indicators and boulders of kimberlite have previously been recovered from the Munro Esker east of Kirkland Lake (Lee 1965; Baker 1982).
4. The work done on the esker samples will be compared with similar work on till samples taken along the flanks of the esker. It may allow for an understanding of how material was fed into the esker system and how it was transported once there. If this can be accomplished then anomalies discovered in the esker stand a much better chance of being traced back to their source.

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S58. Black River-Matheson Economic Geologist Program

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This project is part of Operation Black River-Matheson (BRIM) which was funded equally by the Ontario Ministry of Northern Affairs and Mines and the Ontario Ministry of Natural Resources.

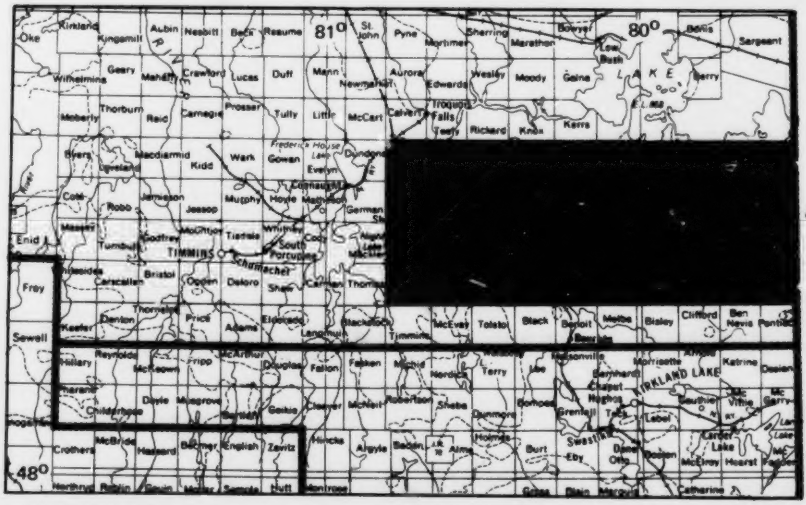
INTRODUCTION

In May 1984, the position of Economic Geologist was established by the office of the Kirkland Lake Resident Geologist as part of Operation Black River-Matheson (BRIM), a multidisciplinary geoscience program focussed on a 40-township block located between Night Hawk Lake and the Ontario-Quebec interprovincial boundary. Based in Kirkland Lake, the Economic Geologist is available to all members of the exploration community, at the local level, as a source of exploration-related information and advice. Efforts of the Economic Geologist are directed toward promoting exploration activity in the BRIM area, and providing services which facilitate exploration. Specifically, the Economic Geologist is available to (1) assist local prospectors with property visits, advice, and assessment file searches; (2) document new mineral occurrences in the BRIM area and more fully describe documented occurrences; (3) compile available data relevant to exploration in the area; and (4) help "orient" those workers or potential workers who are new to the area. A long term goal of the program is to generate a comprehensive, locally accessible computerized database for the BRIM area.

ACTIVITIES

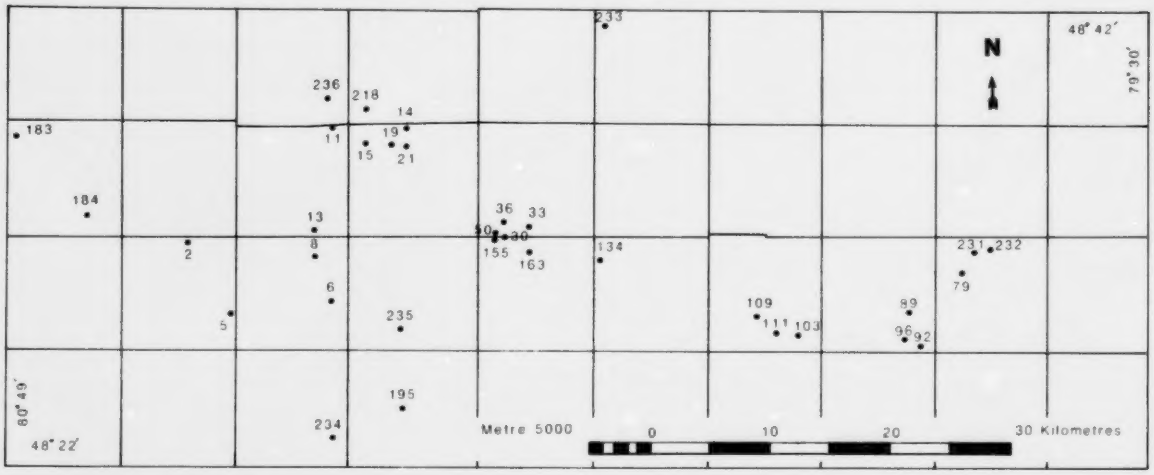
Much of the 1985 field season was spent examining mineral showings within the BRIM area. Individual deposits examined during 1985 are indicated on Figure 1. Descriptions of selected properties will appear in an Ontario Geological Survey publication. In addition to these property visits:

1. A geological compilation map (scale 1:100 000) of the BRIM area has been generated from various previously published provincial maps and reports that were available during the first half of 1985. The map serves to provide a regional geological perspective of the area, attempts to integrate the efforts of many provincial field geologists who have worked in the area during the past 40 years, and offers a basis for evaluating the regional mineral potential. The map is particularly useful for workers new to the area; it may be viewed at the offices of the Resident Geologist in Kirkland Lake and in Timmins, as well as at the Larder Lake Mining Division Drill Core Storage Library in Swastika.
2. A mineralization occurrence map (Figure 2) indicating showings located within the BRIM area has been compiled from sources including the assessment files at the offices of the Resident Geologist in Kirkland Lake and Timmins; provincial Geological Data Inventory Folios (GDIFs), Mineral Deposit Circulars (MRCs), and Source Mineral Deposit Records (SMDRs); and federal National Mineral Inventory (NMI) cards. It should be noted that this map is being updated concurrently with the compilation of GDIFs and is current only through September 1985. A more complete version will appear at a later date.
3. Colour-contoured, calculated magnetic second derivative maps covering the entire BRIM area (scale 1:100 000), derived from the results of the May 1984 Ontario Ministry of Natural Resources BRIM airborne magnetic survey release (Lovell *et al.* 1985, p.166), were obtained in September


81°
80°
48°
QUEBEC
Oke
Kirkland
Kingsmill
Aubin
Nesbitt
Beck
Reaume
St. John
Pyne
Mortimer
Sherring
Marathon
Bowyer
Sargeant
Wilhelmina
Geary
Mahaffy
Crawford
Lucas
Duff
Mann
Newmarket
Aurora
Edwards
Wesley
Moody
Gaina
LAKE
Berry
Moberly
Thorburn
Reid
Carnegie
Prosser
Tully
Little
McCart
Calvert
Iroquois Falls
Teefy
Richard
Knox
Kerrs
Byers
Loveland
Macdiarmid
Kidd
Wark
Gowan
Frederick House Lake
Evelyn
Dundonald
Connaught
Cote
Robb
Jamieson
Jessop
Murphy
Hoyle
Matheson
German
Enid
Massey
Godfrey
McIntyre
Tisdale
Whitney
Cody
Turnbull
TIMMINS
South Porcupine
Schumacher
Frey
Carscallen
Bristol
Ogden
Deloro
Shaw
Carman
Thomas
Sewell
Keefer
Denton
Thorneloe
Price
Adams
Eldorado
Langmuir
Blackstock
Timmins
McEvay
Tolstoi
Black
Benoit
Melba
Bisley
Clifford
Ben Nevis
Pontiac
Hillary
Reynolds
McKeown
Fripp
McArthur
Douglas
Fallon
Fasken
Michie
Nordica
Terry
Lee
Morrisette
Katrine
Dasserat
Bernhardt
KIRKLAND LAKE
Chaput Hughes
Teck
Lebel
Gauthier
McVittie
McGarry
Doyle
Musgrove
Geikie
Cleaver
McNeil
Robertson
Sheba
Dunmore
Gomphf
Grenfell
Childerhose
Crothers
McBride
Hassard
English
Zavitz
Hincks
Argyle
Baden
Alma
Holmes
Burt
Swastika
Eby
Otto
Boston
Larder Lake
McElroy
Hearst
McFadden
Catherine

LOCATION MAP

Scale: 1: 1 584 000 or 1 inch to 25 miles



2. Anderson Occurrence
5. North half lot 1 concession II Occurrence
6. Sylvanite No. 1 Occurrence
8. Sylvanite No. 3 Occurrence
11. Wilcarr Occurrence
13. Black River Occurrence
14. Aljo Prospect
15. Maude Lake Gold Mines Ltd. Prospect
19. Lucky Ben Prospect
21. Blue Quartz Prospect
30. American Eagle Prospect
33. Buff Munro Occurrence
36. Croesus Mine
50. White-Guyatt Occurrence
79. Canamax (Mattawasaga) Prospect
89. Harlight Prospect
92. Iris Occurrence
96. Golden Harker Prospect
103. Bambi Occurrence
109. Buffonta (Kerr Addison Murphy) Mine
111. Deloye Occurrence
134. Kokatow Occurrence
155. Gold Pyramid Prospect
163. Talisman Occurrence
183. Clavos (Canamax) Prospect
184. St. Andrews Goldfields Prospect
195. Mobbs Prospect
218. Pit Occurrence
231. Canamax (42 Zone) Prospect
232. Canamax (East Zone) Prospect
233. Bay Resources Occurrence
234. Hyde Occurrence
235. Gelinas Occurrence
236. Fournier Occurrence

Mine: Includes developing mines and past producers with a minimum production of not less than 100 ounces of gold.

Prospect: Includes occurrences with significant development work, usually consisting of one or more of the following:
a) production of less than 100 ounces of gold,
b) over 30m of underground lateral development work,
c) over 600m of diamond drilling.

Occurrence: Includes showings with little development work performed.

Figure 1. 1985 property visits, Black River-Matheson Economic Geologist. (Project S58.)

TABLE 1. SELECTED DOCUMENTATION FOR MINERALIZATION SHOWINGS, BLACK RIVER – MATHESON AREA (PROJECT S58.)

MAP NUMBER	SHOWING NAME	COMMODITY	SELECTED REFERENCES
1	Turney	Au	GDIF, MDIR C0109, MRC 13 p. 136, OFR 5467, ODM Map P.39, OGS Map 80583
2	Anderson	Au	GDIF, MDIR C0291, NMI 42A/10 Au 1, MRC 13 p. 127, OFR 5467, OGS GR 40 p.14, ODM AR40 pt.3 p.21
3	S. Reid	Au	GDIF, MDIR C0290, NMI 42A/07 Au 6, MRC 13 p. 127, OFR 5467, OGS GR 40, ODM AR40 pt. 3 p. 21
4	Tillex Syndicate	Cu Ag Zn	GDIF, MDIR C0283, NMI 42A/10 Cu 1, ODM GR 40, ODM Map P.856, OGS Map 80593
5	N half lot 1,con. II	Au	NMI 42A/07 Au 7, MRC 13 p.127, ODM AR40 pt.3 p.15, ODM Map P.856, OGS Map 80593
6	Sylvanite No. 1	Au	GDIF, MDIR C0288, NMI 42A/08 Au 3 (Au 22, 1), OFR 5467, MRC 13 p.123, OGS GR40 p.16, OGS Map 80594
7	Sylvanite No. 2	Au	GDIF, MDIR C0287, NMI 42A/10 Au 2 (Au 26), OFR 5467, MRC 13 p. 123, OGS GR40 p.17, OGS Map 80594
8	Sylvanite No. 3	Au	GDIF, MDIR C0286, NMI 42A/09 Au 27, MRC 13 p. 123, ODM GR40 p. 17, ODM Map P.837, OGS Map 80594
9	Pollock-Briscoe	Cu	GDIF, MDIR C0282, NMI 42A/08 Cu 1, MDC 12 p. 131, ODM GR40 p. 18, ODM Map P.837, OGS Map 80594
10	Campbell-Moore	Au	NMI 42A/08 Au 15, MDC 13 p. 123, ODM GR 40, ODM AR40 pt.3, ODM Map P.856, OGS Map 80594
11	Wilcarr (No. 1,2)	Au Cu Zn	GDIF, MDIR C0155, NMI 42A/09 Au 33, OFR 5467, MRC 13 p. 125, ODM AR60 pt.4 p.21, ODM Map P.854
12	Watabeag	Au	GDIF, NMI 42A/10 Au 12, OFR 5467, MRC 13 p. 125, ODM AR60 pt. 4 p. 20, ODM Map P.854, OGS Map 80584
13	Black River	Au	GDIF, NMI 42A/09W Au 17, MRC 13 p. 125, ODM AR60 pt.4 p. 20, ODM Map P.854, OGS Map 80584
14	Aljo	Au	GDIF, MDIR C0153, NMI 42A/09 Au 3, SMDR 2350, MRC 13 p. 45-47, OFR 5467, ODM AR56, pt.7, p. 20-23
15	Maude Lake	Au	GDIF, MDIR C0152, NMI 42A/09 Au 6, SMDR 2351, MRC 13 p.47, OFR 5467, ODM AR56, pt.7, p. 25-26
16	Barton Creek	asb	GDIF, MDIR C0151, NMI 42A/09 asb 6, IMR 36 p. 27, ODM AR67, pt.2, p. 1, ODM AR64 pt.2 p. 1
17	Beatty Syndicate	Au	GDIF, MDIR C0150, NMI 42A/9 Au 19, SMDR 2352, MRC 13 p.123, OFR 5467, ODM AR56 pt.7 p. 26-27
18	Clifford	Au	GDIF, MDIR C0148, NMI 42A/9 Au 42, SMDR 2353, MRC 13 p.123, OFR 5467, ODM AR56 pt.7 p.27
19	Lucky Ben	Au	GDIF, MDIR C0147, SMDR 2354, MRC 13 p.123, NMI 42A/9 Au 22, OFR 5467, ODM AR56 pt.7 p.29
20	Stewart-Abate	Au	GDIF, MDIR C0154, SMDR 2355, NMI 42A/9 Au 2, MRC 13 p.49 and 123, OFR 5467, ODM AR51 pt.1 p.192
21	Blue Quartz	Au	GDIF, NMI 42A/9 Au 1, MRC 13 p. 48, OFR 5467, ODM AR56 pt.7 p.23-25,ODM Map P.864, OGS Map 80585
22	Clodan	Au	MRC 13 p.48 and 123, NMI 42A/9 Au 43, ODM AR56 pt.7 p.27-28, ODM Map P.864, OGS Map 80585
23	Denovo	Au	GDIF, NMI 42A/9 Au 29, MRC 13 p.123, ODM AR56, pt.7 p.28, ODM Map P.864, OGS Map 80585
24	Dunlop	Au	GDIF, NMI 42A/9 Au 30, MRC 13 p.123, ODM AR56 pt.7 p.28, ODM Map P.864, OGS Map 80585
25	Guinea Occurrence	Au	GDIF, NMI 42A/9 Au 24, MRC 13 p.123, ODM AR56 pt.7, p.28, ODM Map P.864, OGS Map 80585
26	Pat Occurrence	Au	GDIF, NMI 42A/9 Au 41, MRC 13 p.123, OFR 5467, ODM AR56 pt.7 p.29, ODM Map P.864, OGS Map 80585
27	J.A. Rhodes	Au	GDIF, NMI 42A/9 Au 25, MRC 13 p.123, ODM AR56 pt.7 p.30, ODM Map P.864, OGS Map 80585
28	Lake OSU	Au	NMI 42A/9 Au (preliminary), ODM AR56 pt.7, ODM Map P.864, OGS Map 80585
29	Ornum	Au	NMI 42A/9 Au (D8), ODM AR56 pt.7, ODM Map P.864, OGS Map 80585
30	American Eagle	Au	GDIF, MDIR C0146, NMI 42A/9 Au 4, OFR 5467 MRC 13 p.80, ODM AR60 pt.8 p.45, OGS Maps P.866, 80586
31	Big Game	Au	GDIF, MDIR C0145, NMI 42A/9 Au 11, OFR 5467, MRC 13 p. 134, ODM AR60 pt.8 p.45, OGS Maps P.866,80586
32	Brown-Munro	Au	GDIF, MDIR C0086, OFR 5467, ODM AR60 pt.8 p.46, OGS Maps P.866, 80586
33	Buff-Munro	Au	GDIF, NMI 42A/9 Au 7, OFR 5467, MRC 13 p. 134, ODM AR60 pt.8 p.47, OGS Maps P.866, 80586
34	Camrose	Au	GDIF, NMI 42A/9 Au 12, MRC 13 p.134, ODM AR60 pt.8 p.47, OGS Maps P.866, 80586
35	Centre Hill	Cu	GDIF, NMI 42A/9 Cu 1, SMDR 830, MRC 12 p.124, MDIR C0143, ODM AR60 pt.8, OGS Maps P.866, 80586
36	Croesus	Au	GDIF, NMI 42A/9 Au 13, MDIR C0140, MRC 13 p.81, OFR 5467, ODM AR60 pt.8 p.48, OGS Maps P.866, 80586
37	A.G.C. Dinnick	Au	GDIF, NMI 42A/9 Au 38, MRC 13 p.134, ODM AR60 pt.8 p.48, OGS Maps P.866, 80586
38	Flagro	asb	GDIF, NMI 42A/9 asb 24, IMR 36 pp.29,57, MDIR C0084, ODM AR60 pt.8 p.41, OGS Maps P.866, 80586
39	H.M. Ford	asb	GDIF, NMI 42A/9 asb 19, IMR 36 pp.29,56, MDIR C0085, ODM AR60 pt.8 p.41, OGS Maps. P.866, 80586
40	King Midas	Au	GDIF, MRC 13 p.134, ODM AR60 pt.8 p.48, OGS Maps P.866, 80586
41	Mangan-Dyer	asb	GDIF, NMI 42A/9 asb 21, MDIR C0142, IMR 36 pp.29,57, ODM AR60 pt.8 p.41, OGS Maps P.866, 80586
42	Northern Gold Belt	Au	GDIF, NMI 42A/9 Au 44, MRC 13 p.134, OFR 5467, ODM AR60 pt.8 p.51, OGS Maps P.866, 80586
43	Munro Mine	asb	GDIF, NMI 42A/9 asb 26 and Fe 2, MRC 11 p.122, MDIR C0139, IMR 36 p.33-41,29, ODM AR60 pt.8
44	Potter-Doal	asb	GDIF, NMI 42A/9 asb 20, MDIR C0144, IMR 36 pp.29,57, ODM AR60 pt.8 p.41, OGS Maps P.866, 80586
45	Potterdoal	Cu	GDIF, NMI 42A/9 Cu 2, MDIR C0141, SMDR 925, MRC 12 p.126, ODM AR60 pt8 p.42, OGS Maps P.866, 80586
46	Reoplate	asb Au	GDIF, NMI 42A/9 Au 34 asb 25, MRC 13 p.134, IMR 36 pp.29,57, ODM AR60 pt.8 p.42, OGS Map P.866,80586
47	W.T. Stewart	Au	GDIF, NMI 42A/9 Au 28, MDIR C0089, OFR 5467, MRC 13 p.134, ODM AR60 pt.8 p.52, OGS Maps P.866, 80586
48	Walhart G.M.L.	Au	GDIF, NMI 42A/9 Au 35, MDIR C0088, OFR 5467, MRC 13 p.134, ODM AR60 pt.8 p.52, OGS Maps P.866, 80586
49	Warden Hill	asb	GDIF, NMI 42A/9 asb 18, MDIR C0083, IMR 36 p.29, ODM AR60 pt.8, OGS Maps P.866, 80586
50	White-Guyatt	Au	GDIF, NMI 42A/9 Au 36, MDIR C0087, OFR 5467, MRC 13 p.81, ODM AR60 pt.8 p.53, OGS Maps P.866, 80586
51	P.B. Zevely	Au	GDIF, NMI 42A/9 Au 37, MRC 13 p.134, ODM AR60 pt.8 p.56, OGS Maps P.866, 80586
52	Centre Creek	asb	NMI 42A/9 asb 27, IMR 36 p.29, ODM AR60 pt.8, OGS Maps P.866, 80586
53	Quebec Asbestos	asb	NMI 42A/9 asb 22, IMR 36 pp.29,57, ODM AR60 pt.8 p.42, OGS Maps P.866, 80586
54	Strongford	asb	NMI 42A/9 asb 23, IMR 36 p.29, ODM AR60 pt.8 p.42, OGS Maps P.866, 80586
55	Lamplugh	Fe	NMI 32D/12 Fe 4, MRC 11 p.121, ODM Map P.799, OGS Maps P.2433, P.2431, 80589
56	Float No. 1	Cu	MRC 17 p.47, ODM Map P.798, OGS Maps P.2433, P.2432, 80590
57	Float No. 2	Cu	MRC 17 p.48, ODM Map P.798, OGS Maps P.2433, P.2432, 80590
58	Island 524SV	Au Cu	GDIF, MDIR C0284, OFR 5467, ODM GR 173 pp.58,61, OGS Maps P.2433, P.2432, 80591
59	Boundary Bay	Au	GDIF, OFR 5467, OGS GR173, OGS Maps P.2432, P.2433, 80591
60	G.C. Roy	Cu	GDIF, MRC 11 p.131, OGS GR173, ODM Map P.824, OGS Maps P.888, P.2432, P.2433, 80601
61	Barrick	Au	GDIF, OFR 5467, MRC 13 p.131, NMI 32D/12 Au 4, ODM AR62 pt.7 p.29, OGS Maps P.2432, P.2433, 80600
62	Coin Lake G.M.L.	Au	GDIF, OFR 5467, MRC 13 p.131, OBM AR34 pt.6 p.95, OBM AR28 pt.2 p.46, OGS Maps P.2432, P.2433
63	Ghostmount	Au	GDIF, MRC 13 p.131, NMI 32D/12 Au4, ODM AR62 pt.7 p.28, OGS Maps P.2433, P.2432, 80600
64	Dominion Gulf	asb	GDIF, NMI 32D/12 asb 9, MDIR C0312, IMR 36 pp.28,60, ODM AR62 pt.7 p.26, OGS Maps P.2433, P.2432
65	Lobanor	Au	GDIF, OFR 5467, MRC 13 p.131, ODM AR62 pt.7 p.29, OGS Maps P.2433, P.2432, 80600
66	Turcott	Au	GDIF, MRC 13 p.123, ODM GR40 p.16, ODM Map P.837, OGS Map 80594
67	ASARCO Exploration	Au	GDIF, ODM GR40 p.16, ODM Map P.837, OGS Map 80594
68	McIntyre	Au	GDIF, MRC 13 p.131, ODM AR62 pt.7 p.30, OGS Maps P.797, P.2433, P.2432, 80600
69	Meridian	Au	GDIF, MRC 13 p.131, ODM AR62 pt.7, OGS Maps P.797, P.2432, P.2433, 80600
70	Mining Corp., E. Gp.	Au	GDIF, MRC 13 p.131, ODM AR62 pt.7 p.31, OGS Maps P.797, P.2433, P.2432, 80600
71	Mining Corp., N. Gp.	Au	GDIF, MDIR C0216, OFR 5467, SMDR C0312(?), ODM AR62 pt.7 p.32, OGS Maps P.797, P.2433, P.2432, 80600
72	O'Neill	Au	GDIF, NMI 32D/12 Au 13, OFR 5467, MRC 13 p.131, ODM AR62 pp.7,32, OGS Map P.797,P.2433,P.2432,80600
73	Remo	Au	GDIF, NMI 32D/12 Au 5, OFR 5467, MRC 13 p.131, ODM AR62 pt.7 p.33, OGS Map P.797,P.2433,P.2432,80600
74	Revere Mining Corp.	Au	GDIF, ODM AR62 pt.7, OGS Maps P.797, P.2433, P.2432, 80600
75	N. Strong	asb	GDIF, NMI 32D/12 asb 8, MDIR C0313, IMR 36 p.28, ODM AR62 pt.7 p.27, OGS Maps P.797, P.2433, P.2432
76	Teddy Bear	Au	GDIF, NMI 32D/12 (prelim.), OFR 5467, MRC 13 p.77, ODM AR62 pt.7 p.33, ODM AR33 pt.3 p.45
77	Holloway	Fe	NMI 32D/12 Fe 3, ODM AR62 pt.7 pp.11,31, OGS Maps P.797, P.2433, P.2432, 80600
78	Matheson	clay	GDIF, MDIR C0285, MDC 15 p. 97, ODM GR 40 p.19, ODM AR 40 pt.3, ODM Map P.837, OGS Map 80594
79	Canamax	Au	ODM AR62 pt.7, OGS Maps P.797, P.2433, P.2432, 80600
80	American Yellowknife	Au	NMI 32D/12 Au 16, ODM AR60 pt.7, OGS Maps P.897, P.2433, P.2431, 80599
81	Anatole Resources	Au	GDIF, NMI 32D/12 Au 2, OFR 5467, MRC 13 p.130, ODM AR60 pt.7, OGS Maps P.897, P.2433, P.2431, 80599
82	Coin Lake	Au	GDIF, MDIR C0315, NMI 32D/5 Au 10, OFR 5467, MRC 13 p.71, ODM AR60 pt.7, OGS Map P.897,P.2432,P.2431
83	Consular Harker	Au	GDIF, MDIR C0314, NMI 32D/12 Au 15, OFR 5467, MRC 13 p.130, ODM AR60 pt.7, OGS Map P.897, P.2433
84	Ben Arch	Au	NMI 32D/12 Au 3, MRC 13 p.130, ODM AR60 pt.7, OGS Maps P.897, P.2433, P.2431, 80599
85	Cortez	Au	NMI 32D/5 Au 11, MRC 13 p.130, ODM AR60 pt.7, OGS Maps P.897, P.2433, P.2431, 80599
86	Dale	Au	NMI 32D/12 Au 9 and Fe 2, MRC 13 p.130, OFR 5467, ODM AR60 pt.7, OGS Maps P.897,P.2433,P.2431,80599
87	Demers	Au	GDIF, MRC 13 p.130, ODM AR60 pt.7, OGS Maps P.897, P.2433, P.2431, 80599
88	N. Harley	Au	GDIF, ODM AR60 pt.7, OGS Maps P.897, P.2433, P.2431, 80599

TABLE 1. CONTINUED.

MAP NUMBER	SHOWING NAME	COMMODITY	SELECTED REFERENCES
89	Harlight	Au	GDIF, MDIR C0318, OFR 5467, MRC 13 p.72, ODM AR60 pt.7, OGS Maps P.897, P.2433, P.2431, 80599
90	Golden Harker	Au	GDIF, MDIR C0318, NMI 32D/5 Au 9, OFR 5467, MRC 13 p.72, ODM AR60 pt.7, OGS Map P.897,P.2433,P.2431
91	Imperial Reserve #1	Au	GDIF, MDIR C0317, NMI 32D/12 and 5 Au 8, OFR 5467, MRC 13 p.130, ODM AR60 pt.7, OGS Map P.897,P.2433
92	Iris	Au	GDIF, MDIR C0316, OFR 5467, MRC 13 p.130, ODM AR60 pt.7, OGS Maps P.897, P.2433, P.2431, 80599
93	Lenora Explorations	Au	GDIF, ODM AR60 pt.7, OGS Maps P.897, P.2433, P.2431, 80599
94	Lightval	Au	GDIF, MRC 13 p.130, ODM AR60 pt.7, OGS Maps P.897, P.2433, P.2431, 80599
95	Imperial Reserve #2	Au	GDIF, OFR 5467, ODM AR60 pt.7, OGS Maps P.897, P.2433, P.2431, 80599
96	Phelps-Dodge Grid B	Au	GDIF, ODM AR60 pt.7, OGS Maps P.897, P.2433, P.2431, 80599
97	Toronto Harker	Au	GDIF,MRC 13 p.130, ODM AR60 pt.7, OGS Maps P.897, P.2433, P.2431, 80599
98	Amax Exploration	Au	GDIF, ODM AR60 pt.7, OGS Maps P.897, P.2433, P.2431, 80599
99	Ghost Mountain Group	asb	NMI 32D/12 asb 6, IMR 36 pp.27,60, ODM AR60 pt.7, OGS Maps P.897, P.2433, P.2431, 80599
100	Hofmann	asb	NMI 32D/12 asb 5, IMR 36 pp.27,60, ODM AR60 pt./, OGS Maps P.897, P.2433, P.2431, 80599
101	Hofman E. Group	asb	NMI 32D/12 asb 7, IMR 36 pp.27,60, ODM AR60 pt.7, OGS Maps P.897, P.2433, P.2431, 80599
102	W.M. Anderson	Au	GDIF, MRC 13 p.127, NMI 32D/12 Au 17, ODM AR58 pt.4, OGS Maps P.868, P.2433, P.2431, 80598
103	Bambi	Au	GDIF, MDIR C0305, NMI 32D/5 Au 4, OFR 5467, MRC 13 p.127, ODM AR58 pt.4 p.17, Map P.868, P.2433
104	Bird-Ginn	asb	GDIF, MDIR C0370, NMI 32D/12 asb 1, IMR 36 pp.27,44,59, ODM AR58 pt.4, OGS Map P.868, P.2433, P.2431
105	S.J. Bird No. 1	Au	GDIF, MRC 13 p.127, ODM AR58 pt.4, OGS Maps P.868, P.2433, P.2431, 80598
106	S.J. Bird No. 2	Au	GDIF, NMI 32D/5 Au 12, MRC 13 p.127, OFR 5467, ODM AR58 pt.4, OGS Maps P.868, P.2433, P.2431, 80598
107	Broulan Porcupine	Au	GDIF, MRC 13 p.127, NMI 32D/5 (42A/8) Au 35, OFR 5467, ODM AR58 pt.4 p.19, OGS Map P.868, P.2433
108	Brydges	Au	GDIF, MDIR C0306, NMI 32D/12 Au 18, OFR 5467, MRC 13 p.127, ODM AR58 pt.4, OGS Map P.868, P.2433
109	Murphy Pit	Au	GDIF, MDIR C0307, NMI 32D/5 Au 7 Au 19(?), OFR 5467, MRC 13 p.68, ODM AR58 pt.4, OGS Map P.868,80598
110	Cominco	Au	NMI 32D/12 Au 14, MRC 13 p.128, ODM AR58 pt.4, OGS Maps P.868, P.2433, P.2431, 80598
111	Deloye	Au	GDIF, NMI 32D/05 Au 18, MRC 13 p.128, ODM AR58 pt.4, OGS Maps P.868, P.2433, P.2431, 80598
112	DiPaulo	Au	GDIF, NMI 32D/12 Au 7, MRC 13 p.128, ODM AR58 pt.4, OGS Maps P.868, P.2433, P.2431, 80598
113	Garrison Creek	Au	GDIF, MRC 13 p.128, NMI 32D/5 Au 15, OFR 5467, ODM AR58, Pt.4, OGS Maps P.868, P.2433, P.2431, 80598
114	Garrison Harbour	Au	GDIF, MDIR C0308, NMI 32D/5 Au 16, OFR 5467, MRC 13 p.128, ODM AR58 pt.4, OGS Maps P.868, P.2433
115	Garrcon	Au	GDIF, MDIR C0309, NMI 32D/12 Au 10, OFR 5467, MRC 13 p.69, ODM AR58 pt.4, OGS Maps P.868, P.2433
116	Grimston	Au	GDIF, MDIR C0310, NMI 32D/5 Au 1, OFR 5467, MRC 13 p.69, ODM AR58 pt.4, OGS Maps P.868,P.2433,80598
117	Hastings	Au	GDIF, MRC 13 p.128, ODM AR58 pt.4, OGS Maps P.868, P.2433, P.2431, 80598
118	Inspiration	Au	GDIF, MRC 13 p.128, ODM AR58 pt.4, OGS Maps P.868, P.2433, P.2431, 80598
119	Linton	Au	GDIF, MRC 13 p.128, ODM AR58 pt.4, OGS Maps P.868, P.2433, P.2431, 80598
120	Mining Corp. No. 1	Au	GDIF, MRC 13 p.128, ODM AR58 pt.4, OGS Maps P.868, P.2433, P.2431, 80598
121	Mining Corp. No. 2	Au	GDIF, MRC 13 p.128, ODM AR58 pt.4, OGS Maps P.868, P.2433, P.2431, 80598
122	Morningdale	Au	GDIF, NMI 32D/12 Au 11, MRC 13 p.128, ODM AR58 pt.4, OGS Maps P.868, P.2433, P.2431, 80598
123	Newfield	Au	GDIF, NMI 32D/12 Au 12, OFR 5467, MRC 13 p.128, ODM AR58 pt.4, OGS Maps P.868, P.2433, P.2431, 80598
124	Shunsby	Au	GDIF, MDIR C0311, NMI 32D/5 Au 17, OFR 5467, MRC 13 p.128, ODM AR58 pt.4, OGS Maps P.868, P.2433
125	Voge	Au	GDIF, MRC 13 p.128, ODM AR58 pt.4, OGS Maps P.868, P.2433, P.2431, 80598
126	Wright-Hargreaves	Au	GDIF, MRC 13 p.128, NMI 32D/12 Au 6, ODM AR58 pt.4, OGS Maps P.868, P.2433, P.2431, 80598
127	Thackeray Creek	Fe	NMI 32D/12 Fe 1, MRC 11 p.116, ODM AR58 pt.4, OGS Maps P.868, P.2433, P.2431, 80598
128	Colonial Asbestos	asb	NMI 32D/12 asb 4, IMR 36 p.27, ODM AR58 pt.4, OGS Maps P.868, P.2433, P.2431, 80598
129	Cdn. Johns Manville	Au	GDIF, ODM AR56 pt.7, ODM Map P.864, OGS Map 80585
130	Anglo-Huronian	Au	NMI 42A/8 Au 12, MRC 13 p.133, ODM AR57 pt.4 p.19, OGS Maps P.871, 80597
131	Caswell	Fe Au	NMI 42A/8 Au 31 and Fe 1, MDIR C0304, OFR 5467, MRC 13 p.133, ODM AR57 pt.4 p.19,OGS Map P.871,80597
132	Clodan	Au	NMI 42A/9 Au 15, MRC 13 p.133, ODM AR57 pt.4 p.20, OGS Maps P.871, 80597
133	Dunmar	Au	NMI 42A/8 Au 28, MRC 13 p.133, OFR 5467, ODM AR57 pt.4 p.20, OGS Maps P.871, 80597
134	Kokatow	Au	MRC 13 p.133, ODM AR57 pt.4 p.21, OGS Maps P.871, 80597
135	Ludgate Lake	Au	NMI 42A/8 Au 36, ODM AR57 pt.4, OGS Maps P.871, 80597
136	Marchaud	Au	MRC 13 p.133, OFR 5467, ODM AR57 pt.4 p.21, OGS Maps P.871, 80597
137	Michaud Porcupine	Au	NMI 42A/9 Au 47, MRC 13 p.133, ODM AR57 pt.4 p.22, OGS Maps P.871, 80597
138	Miller	Au	NMI 42A/8 Au 26, MRC 13 p.133, OFR 5467, ODM AR57 pt.4 p.23, OGS Maps P.871, 80597
139	Transaurum	Au	MRC 13 p.133, ODM AR57 pt.4 p.23, OGS Maps P.871, 80597
140	Wright-Hargreaves	Au	NMI 42A/8 Au 27, MRC 13 p.133, ODM AR57 pt.4 p.24, OGS Maps P.871 80597
141	Gabbro Occurrence	Au	NMI 42A/9 Au 20, MRC 13 p.132, ODM AR61 Pt.5, ODM Map P.822, OGS Map 80587
142	Pillow Lava	Au	NMI 42A/9 Au 45, MRC 13 p.132, ODM AR61 pt.5, ODM Map P.822, OGS Map 80587
143	Bonnacord	Au	MDIR C0076, ODM AR61 pt.5, ODM Map P.822, OGS Map 80587
144	Kirk		NMI 42A/9, ODM AR61 pt.5, ODM Map P.822, OGS Map 80587
145	Northwest Canalask	asb	NMI 42A/9 asb 2, IMR 36 p.28, ODM AR61 pt.5, ODM Map P.822, OGS Map 80587
146	McCool Hill	asb	MDIR C0079, NMI 42A/9 asb 9, IMR 36 pp.28,57, ODM AR61 pt.5, ODM Map P.822, OGS Map 80587
147	Ransom	asb	MDIR C0077, NMI 42A/9 asb 10, IMR 36 p.28, ODM AR61 pt.5, ODM Map P.822, OGS Map 80587
148	Rayville	asb	MDIR C0078, NMI 42A/9 asb 14, IMR 36 p.29, ODM AR61 pt.5, ODM Map P.822, OGS Map 80587
149	Schumacher	asb	NMI 42A/9 asb 7, IMR 36 pp.28,44, ODM AR61 pt.5, ODM Map P.822, OGS Map 80587
150	Quebec Asbestos	asb	NMI 42A/9 asb 13, IMR 36 p.29, ODM AR61 pt.5, ODM Map P.822, OGS Map 80587
151	Gray-Feldman	asb	NMI 42A/9 asb 15, IMR 36 p.29, ODM AR61 pt.5 ODM Map P.822, OGS Map 80587
152	McCool	asb	NMI 42A/9 asb 16, IMR 36 p.28, ODM AR61 pt.5, ODM Map P.822, OGS Map 80587
153	McCool	asb	NMI 42A/9 asb 17, IMR 36 p.29, ODM AR61 pt.5, ODM Map P.822, OGS Map 80587
154	Barlow-Dyer	Au	MDIR C0228, NMI 42A/9 Au 9, MRC 13 p.129, OFR 5467, ODM AR60 Pt.9 p.38, OGS Maps P.872, 80596
155	Gold Pyramid	Au	MDIR C0229, NMI 42A/9 Au 31, MRC 13 p.70, OFR 5467, ODM AR60 pt.9 p.45, OGS Maps P.872, 80596
156	Big Pete	Au	MDIR C0230, NMI 42A/9 Au 16, MRC 13 p.129, OFR 5467, ODM AR60 pt.9 p.40, OGS Maps P.872, 80596
157	Bonter	Au	MDIR C0227, NMI 42A/9 Au 10, MRC 13 p.129, OFR 5467, ODM AR60 pt.9 p.42, OGS Maps P.872, 80596
158	Barrett	Au	NMI 42A/9 Au 14, MRC 13 p.129, ODM AR60 pt.9 p.40, OGS Maps P.872, 80596
159	Caman	Au	NMI 42A/8 Au 16, MRC 13 p.129, OFR 5467, ODM AR60 pt.9 p.48, OGS Maps P.872, 80596
160	Gui-por No. 4	Au	OFR 5467, ODM AR60 pt.9 p.50, OGS Maps P.872, 80596
161	Gold Coin	Au	MRC 13 p.129, NMI 42A/9 Au 21, ODM AR60 pt.9 p.44, OGS Maps P.872, 80596
162	Cominco	Au	OFR 5467, ODM AR60 pt.9, OGS Maps P.872, 80596
163	Talisman	Au	MRC 13 p. 71, OFR 5467, ODM AR60 pt.9 p.47, OGS Maps P.872, 80596
164	Byberg	Au	NMI 42A/8 Au 16, MRC 13 p.129, AR60 pt.9 pp.43,47, OGS Maps P.872, 80596
165	A. Eby	Au	NMI 42A/9 Au 23, MRC 13 p.129, AR60 pt.9 p.43, OGS Maps P.872, 80596
166	Morgan Creek	Au	MRC 13 p.130, ODM AR60 pt.9 p.52, OGS Maps P.872, 80596
167	Canadian Arrow	Au	NMI 42A/8 Au 29, MDIR C0224, MRC 13 p.73, OFR 5467, ODM AR65 pt.5, p.35, ODM Map P.832,OGS Map 80595
168	Gunnar	Au	NMI 42A/8 Au 24, MDIR C0222, MRC 13 p.131, OFR 5467, ODM AR65 pt.5 p.38, ODM Map P.832,OGS Map 80595
169	Kelore	Au	NMI 42A/8 Au 32, MDIR C0226, MRC 13 p.75, OFR 5467, ODM AR65 pt.5 p.45, ODM Map P.832, OGS Map 80595
170	Ross	Au	NMI 42A/8 Au 30, MDIR C0225, OFR 5467, MRC 13 p.76, ODM AR65 pt.5 p.39, ODM Map P.832, OGS Map 80595
171	Vimy	Au	NMI 42A/8 Au 2, MDIR C0223, MRC 13 p.77, OFR 5467, ODM AR65 pt.5, ODM Map P.832, OGS Map 80595
172	Hislop Gold Mines	Au	NMI 42A/9 Au 14, MRC 13 p.74, OFR 5467, ODM AR65 pt.5 p.38, ODM Map. P.832, OGS Map 80595
173	Edross	Au	NMI 42A/8 Au 23, OFR 5467, MRC 13 p.131, ODM AR65 pt.5 p.37, ODM Map P.832, OGS Map 80595
174	Abuy Gold Mines	Au	NMI 42A/9 Au 8, MRC 13 p.131, OFR 5467, ODM AR65 pt.5 p.34, ODM Map P.832, OGS Map 80595
175	Kelore West	Au	OFR 5467, ODM AR65 pt.5, ODM Map P.832, OGS Map 80595
176	Martin-Bird	Au	MRC 13 p.131, ODM AR65 pt.5 p.47, ODM Map P.832, OGS Map 80595

TABLE 1. CONTINUED.

MAP NUMBER	NAME SHOWING	COMMODITY	SELECTED REFERENCES
177	Weir	Au	ODM AR56 pt.5, ODM Map P.832, OGS Map 80595
178	Montclerg	Au	NMI 42A/10 Au 3, MDIR C0094, MRC 13 p.51, OFR 5467, ODM Maps P.308, P.943, OGS Maps P.2335, 80572
179	Gulf	asb	NMI 42A/10 asb 1, MDIR C0123, IMR 36 pp.27,55, ODM Maps P.308, P.943, OGS Maps 80572, P.2335
180	Scott	Ni	MDIR C0124, ODM Maps P.308, P.943, OGS Maps P.2335, 80572
181	Alexo	asb Ni	NMI 42A/10 Ni 1 and asb 3, IMR 36 p.27, MRC 12 p.116, ODM Maps P.308, P.943, OGS Maps P.2335, 80572
182	Dominion Gulf	asb	NMI 42A/10 asb 4, IMR 36 p.27, ODM Maps P.308, P.943, OGS Maps P.2335, 80572
183	Clavos	Au	MDIR C0158, MRC 13 p.136, OFR 5467, NMI 42A/10 Au 16, ODM AR40 pt.3, ODM Map P.38, OGS Map 80582
184	St.Andrews Goldfield	Au	MDIR C0157, OFR 5467, NMI 42A/10 Au 14, ODM AR40 pt.3, ODM Map P.38, OGS Map 80582
185	Nahanni Mines	Au	OFR 5467, ODM AR40 pt.3, ODM Map P.38, OGS Map 80582
186	Seaway	Zn	MDIR C0289, NMI 42A/7 Zn 1, ODM Map P.161, OGS Maps P.2072, 80592, ODM AR40 pt.3
187	lot 2, con. I	Au	OFR 5467, ODM Map P.161, OGS Maps P.2072, 80592, ODM AR40 pt.3
188	J.P. Roy	Au	MDIR C0236, MRC 13 p.136, OFR 5467, ODM AR49 pt.4, OGS Maps P.2074, 80602
189	Cons. Manitoba Mines	Au	OFR 5467, ODM Map P.161, OGS Maps P.2072, 80592, ODM AR40 pt.3
190	Moreau Woodward	Au	OFR 5467, ODM AR49 pt.4, OGS Maps P.2074, 80602
191	Armont	Au	MRC 13 p.136, ODM AR49 pt.4, OGS Maps P.2074, 80602
192	Egan	Fe	NMI 42A/7 Fe 1, MRC 11 p.112, OGS Map 80603
193	Wilkie Mines	F,Au	NMI 42A/7, OGS Map 80603
194	Lightning River	Au	GDIF, MRC 13 p.127, OGS Map 80603
195	Mobb	Au	GDIF, MDIR C0237, MRC 13 p.135, NMI 42A/8 Au 10, OFR 5467, ODM AR31, pt.7, p.20 , ODM AR45 pt.6
196	Ramore	Au	GDIF, NMI 42A/8 Au 21, MRC 13 p.135, OFR 5467, ODM AR45 pt.6, OGS Map P.830, 80605
197	Playfair-Fin	Au	GDIF, NMI 42A/8 Au 25, ODM AR45 pt.6, OGS Maps P.830, 80605
198	Noranda	Au	GDIF, MRC 13 p.135, ODM AR45 pt.6, OGS Maps P.830, 80605
199	Dominion Gulf Grp 2	Au	GDIF, OFR 5467, OGS Maps P.827, 80607
200	Brett-Tretheway	Au	GDIF, OFR 5467, OGS Maps P.827, 80607
201	Bibis	Au	GDIF, MDIR C0213, OFR 5467, OGS GR165, ODM Map P.843, OGS Maps P.850, 80608
202	Garthack	Au	GDIF, MDIR C0238, MRC 13 p.136, OFR 5467, OGS GR165, ODM Map P.843, OGS Maps P.850, 80608
203	Hewitt	Au	GDIF, MDIR C0212, OFR 5467, OGS GR165, ODM Map P.843, OGS Maps, P.850, 80608
204	Keevil	Au	GDIF, MDIR C0211, OFR 5467, OGS GR165, ODM Map P.843, OGS Maps P.850, 80608
205	Dominion Gulf	Au	OGS GR165 p.55., ODM Map P.843, OGS Maps P.850, 80608
206	Ghost Lake	Au	GDIF, MDIR C0210, OFR 5467, OGS GR165, ODM Map P.705, OGS Maps P.2288, 80609
207	Boulder	Au	NMI 32D/5 Au 5, MRC 13 p.127, OGS GR165, ODM Map P.705, OGS Maps P.2288, 80609
208	A. White	Au	MDIR C0214, OFR 5467, OGS GR165, ODM Map P.706, OGS Maps 80610, P.2289
209	Magusi River	Cu	GDIF, MDIR C0215, NMI 32D/5 Cu 3, OGS GR165, ODM Map P.707, OGS Maps P.2285, 80611
210	Argus	Cu Zn	MDIR C0216, ODM Maps P.103, P.857, OGS Map 80573
211	Silver Foam	Au	MRC 13 p.138, ODM Maps P.103, P.857, OGS Map 80573
212	Hollinger	Au	MDIR C0127 OFR 5467, ODM Map P.156, OGS Map 80574
213	Noran	Cu Zn	MDIR C0125, ODM Map P.156, OGS Map 80574
214	Nahanni WI-81-2	Au	OFR 5467, ODM Map P.156, OGS Map 80574
215	Nananni WI-81-1	Au	OFR 5467, ODM Map P.156, OGS Map 80574
216	Mattagami	Au	OFR 5467, ODM Map P.156, OGS Map 80574
217	Falls	Au	MDIR C0131, ODM Maps P.157, P.852, OGS Map 80575
218	Pit	Au	MDIR C0132, OFR 5467, ODM Maps P.157, P.852, OGS Map 80575
219	Shallow River	Au	OFR 5467, ODM Maps P.852, P.157, OGS Map 80575
220	Hedman	asb	MDIR C0082, IMR 36 p.30, 56, 50-52, MRC 12 p.125-126, NMI 42A/9 asb 1, ODM Map P.775, OGS Map 80576
221	Noranda	Au	MDIR C0080, OFR 5467, ODM Map P.775, OGS Map 80576
222	Stairs	asb	MDIR C0081, NMI 42A/9 asb 5, IMR 36 pp.30,56, ODM Map P.775, OGS Map 80576
223	Warden	asb	NMI 42A/9 asb 4, IMR 36 p.30, ODM Map P.775, OGS Map 80576
224	Jensen	Au	MDIR C0179, ODM Map P.821, OGS Maps P.2431, P.2433, 80588
225	Lobanor No. 1	Au	OFR 5467, ODM AR62 pt.7, OGS Maps P.797, P.2433, P.2432, 80600
226	Lobanor No. 2	Au	OFR 5467, ODM AR62 pt.7, OGS Maps P.797, P.2433, P.2432, 80600
227	Lobanor No. 3	Au	OFR 5467, ODM AR62 pt.7, OGS Maps P.797, P.2433, P.2432, 80600
228	Imperial Reserve No2	Au	OFR 5467, ODM AR60 pt.7, OGS Maps P.897, P.2433, P.2431, 80599
229	Claim Tp. 43	Au	MDIR C0106, MRC 13 p. 123
230	Shaft Island	Au	MRC 13 p. 123
231	Canamax	Au	ODM AR62 Pt.7, OGS Maps P.797, P.2433, P.2432, 80600
232	Canamax	Au	ODM AR62 pt.7, OGS Maps P.797, P.2433, P.2432, 80600
233	Bay Resources	Au	ODM Map P.772, OGS Map 80577
234	Hyde	Au	ODM AR45 pt.6, OGS Maps P.2052, 80604
235	Gelinas	Au	ODM AR65 pt.5, ODM Map P.832, OGS Map 80595
236	Fournier, E.	Au	ODM Map P.156, OGS Map 80574
237	Bonwitha Mining Co.	Au	GDIF, OGS Maps p.827, 80607
238	Cooper, F.L.	Au	GDIF, OGS Maps P.827, 80607
239	Noranda Expl.Co.Ltd.	Au	GDIF, OGS Maps P.827, 80607
240	Cortez Expl.Co.Ltd.	Au	GDIF, OGS GR165, ODM Map P.843, OGS Maps P.850, 80608
241	Temple G.M. Ltd.	Au	GDIF, ODM AR45 pt.6, OGS Maps P.830, 80605
242	Tremblay, F.	Au	GDIF, ODM AR45 pt.6, OGS Maps P.830, 80605
243	Crossan, P.	Au	GDIF, OGS GR165, ODM Maps P. 706, P.2289, OGS Map 80610
244	McClosky, J.A.	Au	GDIF, OGS GR165, ODM Map P.706, OGS Maps P.2289, 80610
245	Caramora Porc. M.L.	Au	GDIF, ODM AR45 pt.6, OGS Maps P.2052, 80604
246	Stevens, N.D.	Au	GDIF, ODM AR45 pt.6, OGS Maps P.2052, 80604
247	Randa, T.	Au Ag	GDIF, OGS GR165, ODM Map P.705, OGS Maps P.2288, 80609
248	Lambroff Lucky Strik	Au	GDIF, OGS Maps P.829, 80606
249	Marshall-Guitard	Au	GDIF, OGS Maps P.829, 80606
250	New Kelore M.L.	Au Ag	GDIF, OGS Maps p.829, 80606
251	Pion, T.	Au	GDIF, OGS Maps P.829, 80606
252	St. Joe Canada Inc.	Au	GDIF, OGS Maps P.829, 80606

Abbreviations:

AR- Annual Report
GDIF- OGS Township Geological Data Inventory Folio
GR- Geological Report
IMR- ODM Industrial Mineral Report
MDIR- OGS Mineral Deposit Inventory Record
MDC- OGS Mineral Deposit Circular
MRC- ODM Mineral Resource Circular
NMI- Federal National Mineral Inventory
OFR- ODM or OGS Open File Report
SMDR- OGS Source Mineral Deposit Record

Map number refers to locations indicated in Figure 2.

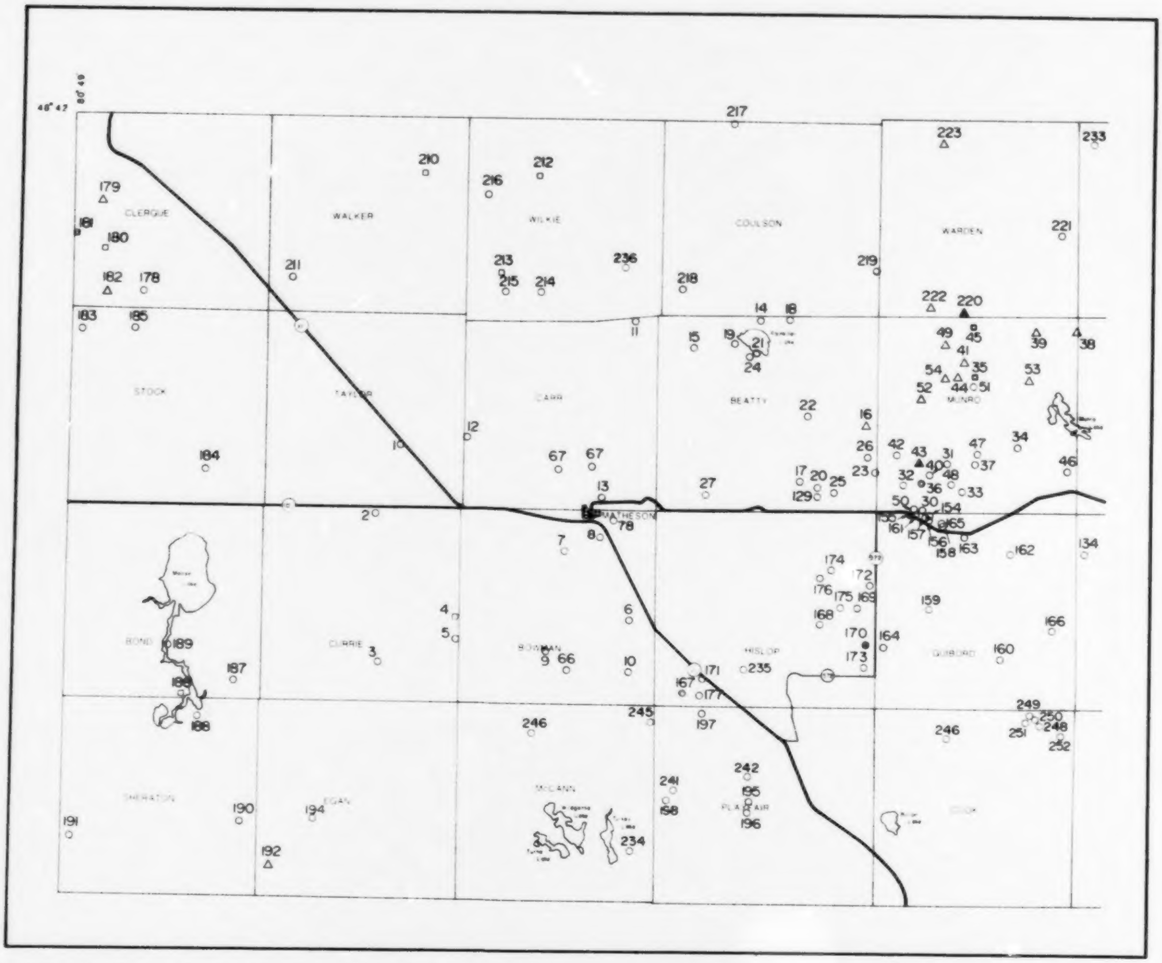
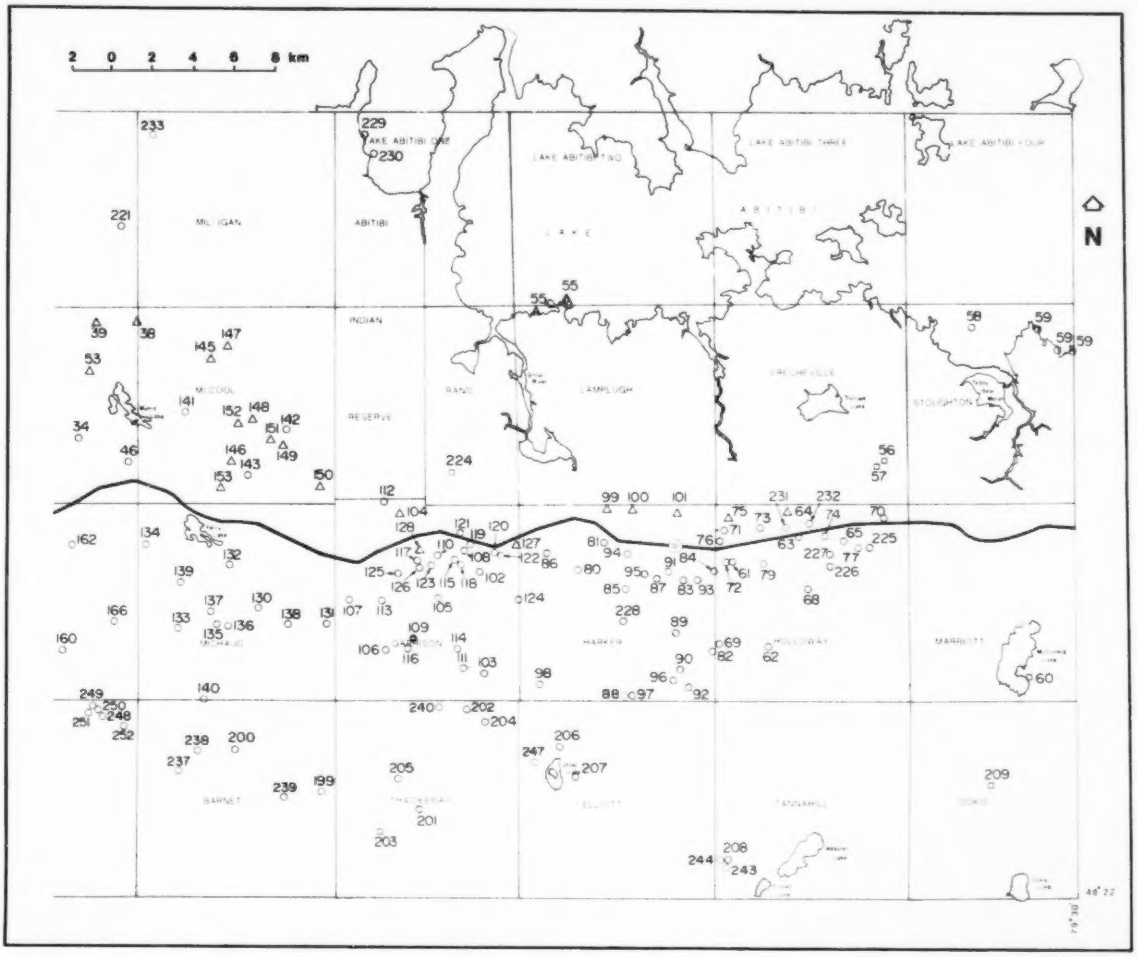

48°47
80°49
CLERGUE
WALKER
WILKIE
COULSON
WARDEN
STOCK
TAYLOR
CARR
BEATTY
MUNRO
MATHESON
BOND
CURRIE
BOWMAN
HISLOP
GUIBORD
SHERATON
EGAN
McCANN
PLAYFAIR
COOK

Figure 2. Mineralization location map, Black River-Matheson Area. (Project S58.)

MAP NUMBER	SHOWING NAME	ALTERNATE NAME(S)	COMMODITY
1	Turney	N.A. Timmins Explor.	Au
2	Anderson		Au
3	S. Reid		Au
4	Tillex Syndicate	Currie	Cu Ag Zn
5	N half lot 1,con. II		Au
6	Sylvanite No. 1	Bowman	Au
7	Sylvanite No. 2	Bowman Twp.	Au
8	Sylvanite No. 3		Au
9	Pollock-Briscoe	Devil's Elbow,Copper	Cu
10	Campbell-Moore		Au
11	Wilcarr (No. 1,2)		Au Cu Zn
12	Watabeag		Au
13	Black River		Au
14	Aljo		Au
15	Maude Lake	Argyll	Au
16	Barton Creek	C Asbestos Body	asb
17	Beatty Syndicate		Au
18	Clifford		Au
19	Lucky Ben	Painkiller Lake	Au
20	Stewart-Abate	Texas Gulf Sulfur	Au
21	Blue Quartz	Headwater	Au
22	Clodan		Au
23	Denovo		Au
24	Dunlop		Au
25	Guinea Occurrence		Au
26	Pat Occurrence		Au
27	J.A. Rhodes		Au
28	Lake OSU	uncertain location	Au
29	Ornum	uncertain location	Au
30	American Eagle		Au
31	Big Game		Au
32	Brown-Munro		Au
33	Buff-Munro		Au
34	Camrose		Au
35	Centre Hill	Potter Mine	Cu
36	Croesus		Au
37	A.G.C. Dinnick		Au
38	Flagro		asb
39	H.M. Ford		asb
40	King Midas		Au
41	Mangan-Dyer		asb
42	Northern Gold Belt		Au
43	Munro Mine	Wood Croesus	asb
44	Potter-Doal		asb
45	Potterdoal		Cu
46	Reoplata		asb Au
47	W.T. Stewart		Au
48	Walhart G.M.L.		Au
49	Warden Hill		asb
50	White-Guyatt		Au
51	P.B. Zevely		Au
52	Centre Creek		asb
53	Quebec Asbestos	Mangan	asb
54	Strongford		asb
55	Lamplugh		Fe
56	Float No. 1		Cu
57	Float No. 2		Cu
58	Island 524SV	Jensen	Au Cu
59	Boundary Bay	Nufort	Au
60	G.C. Roy	Marriott	Cu


2 0 2 4 6 8 km
N
LAKE ABITIBI ONE
LAKE ABITIBI TWO
LAKE ABITIBI THREE
LAKE ABITIBI FOUR
ABITIBI
LAKE
MILLIGAN
ABITIBI
INDIAN RESERVE
MCCOOL
RAND
LAMPLUGH
FRECHEVILLE
STOUGHTON
MICHAUD
GARRISON
HARKER
HOLLOWAY
MARRIOTT
BARNET
THACKERAY
ELLIOTT
TANNAHILL
DOKIS
48°22'
79°30'

MAP NUMBER	SHOWING NAME	ALTERNATE NAME(S)	COMMODITY
61	Barrick	Camflo, McDermott	Au
62	Coin Lake G.M.L.	Lightning River	Au
63	Ghostmount	Canamax	Au
64	Dominion Gulf		asb
65	Lobanor		Au
66	Turcott		Au
67	Asarco Exploration		Au
68	McIntyre		Au
69	Meridian		Au
70	Mining Corp., E. Gp.		Au
71	Mining Corp., N. Gp.		Au
72	O'Neill	Barrick	Au
73	Remo		Au
74	Revere Mining Corp.		Au
75	N. Strong		asb
76	Teddy Bear		Au
77	Holloway		Fe
78	Matheson		clay
79	Canamax	Mattawasaga	Au
80	American Yellowknife		Au
81	Anatole Resources	Bellingham	Au
82	Coin Lake		Au
83	Consular Harker		Au
84	Ben Arch		Au
85	Cortez		Au
86	Dale		Au
87	Demers		Au
88	N. Harley	Toronto Harker (?)	Au
89	Harlight		Au
90	Golden Harker	Harker G.M.L.	Au
91	Imperial Reserve #1		Au
92	Iris		Au
93	Lenora Explorations		Au
94	Lightval		Au
95	Imperial Reserve #2	Newmex Gold Res.	Au
96	Phelps-Dodge Grid B	Harker	Au
97	Toronto Harker	Harley (?)	Au
98	Amax Exploration		Au
99	Ghost Mountain Group		asb
100	Hofmann		asb
101	Hofman E. Group		asb
102	W.M. Anderson		Au
103	Bambi		Au
104	Bird-Ginn		asb
105	S.J. Bird No. 1		Au
106	S.J. Bird No. 2		Au
107	Broulan Porcupine		Au
108	Brydges		Au
109	Murphy Pit	Buffonta, Amca	Au
110	Cominco		Au
111	Deloye		Au
112	DiPaulo		Au
113	Garrison Creek		Au
114	Garrison Harbour		Au
115	Garrcon		Au
116	Grimston	Golden Croesus	Au
117	Hastings		Au
118	Inspiration		Au
119	Linton		Au
120	Mining Corp. No. 1		Au

FIGURE 2. LEGEND. CONTINUED.

MAP NUMBER	NAME SHOWING	ALTERNATE NAME(S)	COMMODITY
121	Mining Corp. No. 2		Au
122	Morningdale		Au
123	Newfield		Au
124	Shunsby		Au
125	Voge		Au
126	Wright-Hargreaves		Au
127	Thackeray Creek		Fe
128	Colonial Asbestos	Normalloy	asb
129	Cdn. Johns Manville		Au
130	Anglo-Huronian		Au
131	Caswell		Fe Au
132	Clodan		Au
133	Dunmar		Au
134	Kokatow		Au
135	Ludgate Lake		Au
136	Marchaud		Au
137	Michaud Porcupine		Au
138	Miller		Au
139	Transaurum		Au
140	Wright-Hargreaves		Au
141	Gabbro Occurrence		Au
142	Pillow Lava		Au
143	Bonnacord		Au
144	Kirk	uncertain location	
145	Northwest Canalask		asb
146	McCool Hill	Camrose Gold, Metals	asb
147	Ransom	Dominion Gulf Grp. 1	asb
148	Rayville		asb
149	Schumacher		asb
150	Quebec Asbestos		asb
151	Gray-Feldman		asb
152	McCool	Cdn Johns Manville	asb
153	McCool	Cdn Johns Manville	asb
154	Barlow-Dyer		Au
155	Gold Pyramid		Au
156	Big Pete		Au
157	Bonter		Au
158	Barrett		Au
159	Caman		Au
160	Gui-por No. 4		Au
161	Gold Coin		Au
162	Cominco		Au
163	Talisman		Au
164	Byberg	Gunnar G.M.L.	Au
165	A. Eby		Au
166	Morgan Creek		Au
167	Canadian Arrow	Golden Arrow	Au
168	Gunnar		Au
169	Kelore	Kelwren M.L.	Au
170	Ross	Pamour, Hollinger	Au
171	Vimy		Au
172	Hislop Gold Mines		Au
173	Edross		Au
174	Abuy Gold Mines		Au
175	Kelore West		Au
176	Martin-Bird		Au
177	Weir		Au
178	Montclerg		Au
179	Gulf	Dominion Gulf	asb
180	Scott		Ni
181	Alexo		asb Ni
182	Dominion Gulf		asb
183	Clavos		Au
184	St.Andrews Goldfield	Quebec Sturgeon	Au
185	Nahanni Mines		Au
186	Seaway	Sheraton Lake	Zn
187	lot 2, con. 1		Au
188	J.P. Roy		Au
189	Cons. Manitoba Mines		Au
190	Moreau Woodward		Au
191	Armont		Au
192	Egan		Fe
193	Wilkie Mines	uncertain location	F,Au
194	Lightning River		Au
195	Mobb		Au
196	Ramore		Au
197	Playfair-Fin		Au
198	Noranda		Au
199	Dominion Gulf Grp 2		Au
200	Brett-Tretheway		Au
201	Bibis		Au
202	Garthack		Au
203	Hewitt		Au
204	Keevil		Au
205	Dominion Gulf		Au
206	Ghost Lake		Au
207	Boulder		Au
208	A. White		Au
209	Magusi River		Cu
210	Argus		Cu Zn
211	Silver Foam		Au
212	Hollinger		Au
213	Noran		Cu Zn
214	Nahanni WI-81-2		Au
215	Nanenni WI-81-1		Au
216	Mattagami		Au
217	Falls		Au
218	Pit		Au
219	Shallow River		Au
220	Hedman		asb
221	Noranda		Au
222	Stairs		asb
223	Warden		asb
224	Jensen		Au
225	Lobanor No. 1		Au
226	Lobanor No. 2		Au
227	Lobanor No. 3		Au
228	Imperial Reserve No2		Au
229	Claim Tp. 43		Au
230	Shaft Island		Au
231	Canamax	42 Zone	Au
232	Canamax	East Zone	Au
233	Bay Resources		Au
234	Hyde		Au
235	Gelinas		Au
236	Fournier, E.		Au
237	Bonwitha Mining Co.		Au
238	Cooper, F.L.		Au
239	Noranda Expl.Co.Ltd.		Au
240	Cortez Expl.Co.Ltd.		Au
241	Temple G.M. Ltd.		Au
242	Tremblay, F.		Au
243	Crossan, P.		Au
244	McClosky, J.A.		Au
245	Caramora Porc. M.L.		Au
246	Stevens, N.D.		Au
247	Randa, T.		Au Ag
248	Lambroff Lucky Strike Gold Syndicate		Au
249	Marshall-Guitard		Au
250	New Kelore M.L.		Au Ag
251	Pion, T.		Au
252	St. Joe Canada Inc.		Au

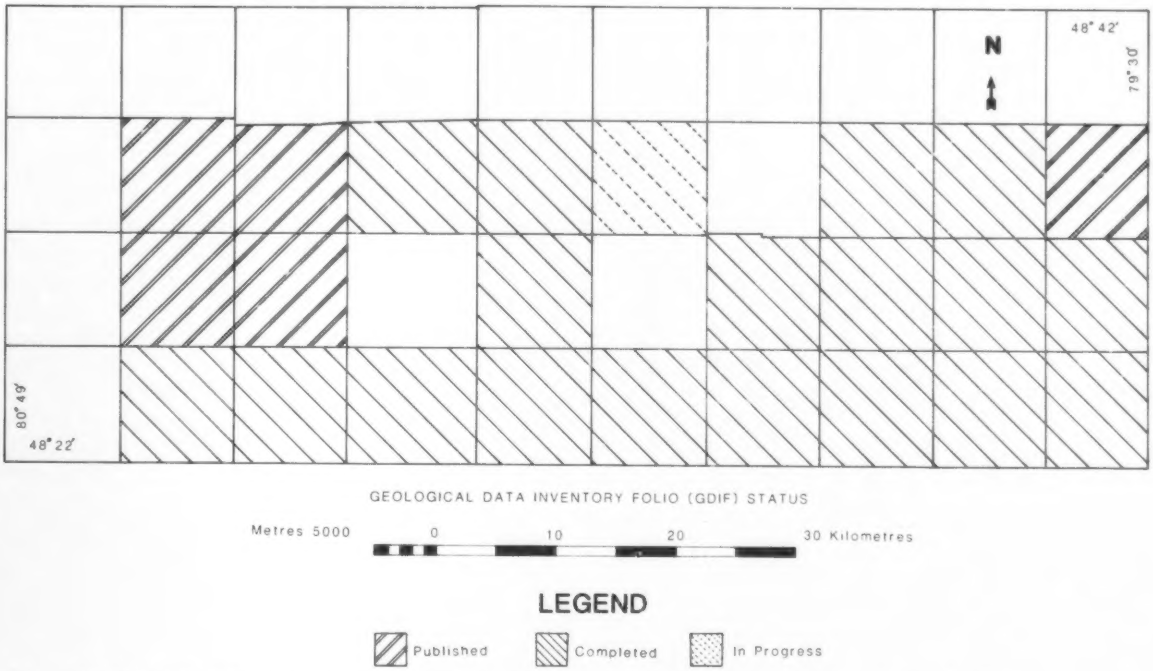


Figure 3. Geological Data Inventory Folio (GDIF) status, Black River-Matheson Area. (Project S58.)

1985. Maps such as the magnetic first vertical derivative (i.e. gradient), and the magnetic second vertical derivative (i.e rate of change of gradient), are useful because they enhance local field variation that may be masked by trends in the total field that are more regional in extent. Subtle magnetic trends, inferred to be caused by (for example) bedrock geological contacts or faults that would not otherwise be readily apparent on a total field map, may thus be enhanced or revealed by such data massage. These maps are available for inspection at the offices of the Resident Geologist in Kirkland Lake and Timmins, at the Larder Lake Mining Division Drill Core Storage Library, in Swastika, and through the Geophysics/Geochemistry Section, Ontario Geological Survey, Toronto.

4. In cooperation with D. Guindon, Larder Lake Mining Division Drill Core Storage Library Geologist, work is in progress to develop a locally accessible computerized database. When operable, the system will be menu driven, and will allow the user to access cross indexed BRIM data pertaining to the assessment files at the offices of the Resident Geologists, core and rock samples stored at Larder Lake and Porcupine Mining Division Drill Core Storage Libraries, mineral showings, and literature references. As of September 1985, more than 750 keyword cross referenced literature articles pertinent to the mineral potential of the BRIM area have been stored on floppy disks accessible via the Apple® IIe computer and software available at the Larder Lake and Porcupine Mining Division Core Storage Libraries. Selected documentation pertaining to the showings located in Figure 2 is listed as Table 1.

5. A map (scale 1:100 000) has been compiled indicating the locations of diamond-drill holes and Ontario Geological Survey sonic drillholes within the BRIM area, which are stored at the Larder Lake and Porcupine Mining Division Drill Hole Core Storage Libraries.

6. Compilation of township Geological Data Inventory Folios (GDIFs) by the staff at the office of the Resident Geologist in Kirkland Lake is ongoing (Figure 3). As of September 1985, GDIFs for the townships of Bowman, Carr, Currie, Stoughton, and Taylor (GDIF numbers 271, 265, 270, 269, and 264, respectively) have been published. Compilation has been completed for the townships of Barnet, Beatty, Cook, Dokis, Egan, Elliott, Frecheville, Garrison, Guibord, Harker, Holloway, Lamplugh, Marriott, McCann, Munro, Playfair, Tannahill, and Thackeray; published GDIFs for these townships are expected to be available in the near future.

7. In cooperation with K.D. Kalicharran, Data Geologist, an investigation is in progress concerning the potential application of remotely sensed data to mineral exploration in the BRIM area. This study currently involves visual interpretation of Landsat multispectral scanner (MSS) and computer enhanced MSS data, Seasat-SAR radar imagery, and stereoscopic analysis of black and white air photography.

8. BRIM poster displays were presented at the Matheson Fall Fair in August and at the Canadian Institute of Mining Second District Three Meeting in Timmins in October.

ADVICE TO PROSPECTORS

Historically, substantial exploration activity for gold has been concentrated along both the Porcupine-Destor and Pipestone Fault zones, where auriferous quartz-carbonate veins and stringers are typically hosted by various carbonate-, sericite-, chlorite-, talc- and serpentine-bearing schists. The gold occurs both in the native state and associated with pyrite. Associated ore minerals may include arsenopyrite, chalcopyrite, and galena (Resident Geologist Files, Kirkland Lake). Similarly, much activity has been directed towards locating auriferous quartz-carbonate vein systems associated with intrusive felsic stocks. Such mineralization may occur either internally or externally to the associated felsic intrusive body and may be accompanied by silicification, pyritization, carbonatization and/or hematitization (Cherry 1982).

Recent encouraging results on the Barrick Resources Corporation (formerly Camflo Mines Limited) McDermott and adjoining claim groups and the Canamax Resources Incorporated Mattawasaga 42, and East zones in Holloway Township (The Northern Miner, August 29, 1985; July 11, 1985; June 20, 1985; March 7, 1985; February 21, 1985; February 14, 1985; December 27, 1984; December 22, 1983; Northern American Gold Industry News, March 15, 1985) have resulted in substantial exploration activity for similar gold mineralization elsewhere in the BRIM area. McDermott-type mineralization consists of native gold within and on pyrite (A.W. Workman, Project Geologist, Barrick Resources Corporation, personal communication, 1985) confined to pods occurring within pale purple hematitic, pyritic, carbonatized, and silicic rocks of controversial origin.

Historically, the host rocks have been variously described as silicified basalt, rhyolite, and felsitized andesite (Resident Geologist Files, Kirkland Lake). More recently, a sedimentary origin for the mineralized zone has been suggested (A.W. Workman, personal communication). The deposit's country rocks are tholeiitic basalts of the Kinojevis Group, as indicated by Jensen (1982a, 1982b). Regional east-northeast-trending faults transect the deposit area, and the Porcupine-Destor Fault zone is located a short distance north of the McDermott and Mattawasaga discoveries. Barrick Resources has established mineralization in this gold-bearing zone over a strike length of several kilometres by diamond drilling in an area of very poor outcrop exposure. The anomalous zone coincides with a broad magnetic low of regional extent.

A large portion of the bedrock geology underlying the BRIM area south of the Porcupine-Destor Fault zone consists of low metamorphic rank, dominantly tholeiitic Kinojevis Group volcanic rocks, and interbedded sediments (MERQ-OGS 1983) which are characterized by a well defined magnetic stratigraphy consisting of alternating bands of magnetic highs and lows (Ontario Geological Survey 1984). Kinojevis stratigraphy, as elucidated by airborne magnetic data, may be traced more or less continuously over strike distances of 75 km with only minor disruptions due to cross-faulting and the intrusion of felsic stocks. In the Harker-Holloway Township area, multiple discrete horizons of what has been variously interpreted as (meta) tuff, chert, tuff breccia, cherty tuff, dacite, rhyolite, partially silicified or carbonatized mafic volcanic rocks, and fault zones (Jensen 1982a, 1982b; Satterly 1954, 1952), most of which may be variably pyritic and carry anomalous gold values at various places along their strike, are found to be associated with discrete magnetic lows of regional extent.

Much of the exploration work currently taking place in the southeast-central BRIM area is being focused along these horizons and their strike extensions as elucidated by the Kinojevis magnetic signature, in hope of locating mineralization analogous to that already delineated by Barrick Resources and Canamax Resources. Should these hopes be borne out, the apparent continuity of Kinojevis Group stratigraphy south of the Porcupine-Destor Fault zone would appear to indicate that analogous mineralization could be expected to occur as far west along strike as the Bowman-McCann-Playfair-Hislop Township area (a distance of about 50 km). Mineralization analogous to that found in the Holloway-Harker area may also occur north of the Porcupine-Destor Fault zone within Kinojevis Group rocks underlying parts of Stoughton and Frecheville Townships. Described occuring here, especially in the lower 1000 m of the Kinojevis section, are felsic and sedimentary rocks such as "...interflow units of tuff-breccia, crystal tuff and cherty tuff of calc-alkalic dacite and rhyolite composition, as well as chert, argillite, graphite and cherty oxide iron formation (Figure 53)..." (Jensen and Langford 1983, p.234).

Calc alkalic rocks of the Hunter Mine Group (which underlie major portions of Walker, Wilkie, Coulson, Warden, Milligan, McCool, Rand, Lamplugh, and Frecheville Townships) and the Blake River Group (which underlie major portions of Marriott, Dokis, Tannahill, and Elliott Townships) (OGS-MERQ 1983) are potentially host to volcanogenic Pb-Zn-Cu-Au-Ag sulphide mineralization. An inferred positive relief during Blake River Group deposition has led Jensen (1980) to postulate that such mineralization, if present in the Blake River Group section, is likely to be located proximal to volcanic vent locations and could be of "stacked" form.

Komatiitic-affinity Stoughton-Roquemaure Group volcanic rocks underlie much of the central and northwestern BRIM area, and are potentially host to nickel sulphide mineralization and to industrial minerals including asbestos, serpentine bulk filler, magnesite, and talc. The Hedman Mine in southern Warden Township is a serpentine deposit currently in production (Whittaker and Malczak 1984).

The presence of kimberlite dikes in Michaud Township (Jensen 1975) and of kimberlite boulders in glacial overburden in the Kirkland Lake-Larder Lake area (Baker 1982; G. Grabowski, Resource Geologist, Ontario Ministry of Northern Affairs and Mines, Kirkland Lake, personal communication) suggest that the BRIM area has the potential to host diamonds both in bedrock and possibly in placers associated with eskers in the Quaternary section. The potential for placer gold associated with eskers in the BRIM area is being investigated.

ACKNOWLEDGMENTS

Thanks are due to V.R. Slaney and J.R. Harris of the RADARSAT Project Office (Ottawa) for helpful discussion and access to Seasat-SAR radar imagery. Bill Bruce and the staff of the Canada Centre for Remote Sensing (Ottawa) generously donated their time and use of computer facilities for enhancement of Landsat MSS data. The author has benefitted greatly from discussion with G. Hinse, L. Jensen, D. Johnstone, H. Lovell, J. Malczak, D. Pitcher, and P. Whittaker. N. Cox provided able field assistance. The cooperation of numerous company geologists also is gratefully acknowledged.

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S59. Metallogenetic Studies in the Black River-Matheson Area, District of Cochrane

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This project is part of Operation Black River-Matheson (BRIM) which was funded equally by the Ontario Ministry of Northern Affairs and Mines and the Ontario Ministry of Natural Resources.

INTRODUCTION

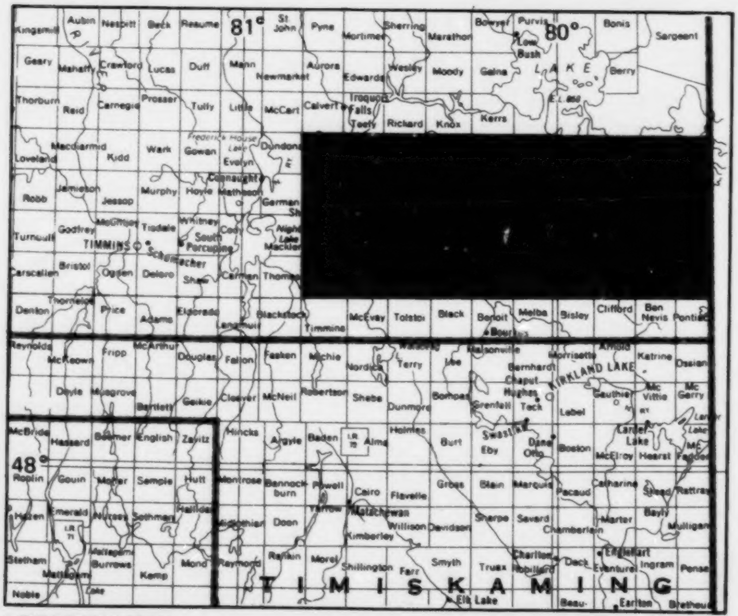
Studies of mineralization in the Black River-Matheson (BRIM) area were begun by the Mineral Deposits Section in 1984 (Whittaker and Malczak 1984) in order to establish a regional metallogenetic framework, with emphasis on gold, for the area. Recent geological mapping in the area (Jensen 1978, 1982; Trowell and Johnstone 1983) serves to establish the lithotectonic framework which is prerequisite to such metallogenetic studies. The importance of this work has been significantly increased by recent exploration activity in the area, notably, by Barrick Resources Corporation and Canamax Resources Incorporated.

The initial year of the program included reconnaissance investigations of mineral occurrences in the BRIM area, with detailed mapping of the Teddy Bear Valley (Seager's Hill) deposit in Holloway Township (Whittaker and Malczak 1984). In 1985, detailed mapping was done in the area of Croesus and White-Guyatt deposits in Munro Township, in west central Thackeray Township and northwestern Harker Township adjacent to Holloway Township to further document the geology of gold mineralization in the BRIM area.

CROESUS—WHITE GUYATT AREA

Detailed mapping in the area of the Croesus and White-Guyatt gold deposits (Satterly 1952b), north of the Destor-Porcupine Fault Zone in Munro Township, was done to examine the gold environments in metavolcanic (Croesus) and metasedimentary (White-Guyatt) host rocks (Location Map).

Free gold is hosted by quartz veins in both deposits. At the Croesus Mine, economic quartz veining, hosted by metavolcanics, is a distinctive grey to bluish grey colour. In contrast, vein quartz at the uneconomic White-Guyatt deposit, 1 km southwest of the Croesus Mine, is white and occurs in thickly bedded lithic sandstones to wackes. As well, the degree of alteration differs strongly in the two deposits: alteration of the metasediments at the White-Guyatt deposit reflects only regional greenschist facies metamorphism, with more argillaceous rocks being well sericitized; whereas alteration of metavolcanics in the immediate Croesus shaft area is intense. Here, the grey quartz vein cuts a 15 to 20 m wide area of strongly foliated, sericitized, pyritic pillow basalt. Veining post-dates shearing and alteration; underground workings mined the richly mineralized quartz vein where it intersected sheared, altered metabasalt.


81°
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Kingsmill
Aubin
Nesbitt
Beck
Reaume
St. John
Pyne
Mortimer
Sherring
Marathon
Bowyer
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Bonis
Sergeant
Geary
Mahaffy
Crawford
Lucas
Duff
Mann
Newmarket
Aurora
Edwards
Wesley
Moody
Geina
LAKE
Berry
Thorburn
Reid
Carnegie
Prosser
Tully
Little
McCart
Calvert
Iroquois Falls
Teefy
Richard
Knox
Kerrs
Macdiarmid
Loveland
Kidd
Wark
Gowan
Frederick House Lake
Dundonald
Evelyn
Connaught
Robb
Jamieson
Jessop
Murphy
Hoyle
Matheson
German
Turnbull
Godfrey
Tisdale
Whitney
Night Hawk Lake
South Porcupine
Mackler
TIMMINS
Schumacher
Carscallen
Bristol
Ogden
Deloro
Shaw
Carman
Thomas
Denton
Thornloe
Price
Adams
Eldorado
Langmuir
Blackstock
Timmins
McEvay
Tolstoi
Black
Benoit
Bourkes
Melba
Bisley
Clifford
Ben Nevis
Pontiac
Reynolds
McKeown
Fripp
McArthur
Douglas
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Michie
Nordica
Terry
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Maisonville
Morrisette
Arnold
Katrine
Ossian
Doyle
Musgrove
Bartlett
Geikie
Cleaver
McNeil
Robertson
Shebe
Dunmore
Bompas
Bernhardt
Chaput
Hughes
Grenfell
Teck
KIRKLAND LAKE
Lebel
Gauthier
Mc Vittie
Mc Garry
McBride
Hassard
Beemer
English
Zavitz
Hincks
Argyle
Baden
Alma
Holmes
Burt
Eby
Otto
Boston
McElroy
Larder Lake
Hearst
Lake
Rollin
Gouin
Sample
Hutt
Montrose
Bannockburn
Powell
Cairo
Flavelle
Gross
Blain
Marquis
Pacaud
Catharine
Rattray
Emerald
Halliday
Yarrow
Matachewan
Willison
Davidson
Sharpe
Savard
Chamberlain
Marter
Bayly
Mulligan
Doon
Kimberley
Burrows
Kemp
Mond
Raymond
Rankin
Morel
Shillington
Farr
Smyth
Truax
Charlton
Dack
Englehart
Evanturel
Ingram
Pense
Noble
TIMISKAMING
Elk Lake
Beauchamp
Earlton
Brethour

LOCATION MAP

Scale : 1 : 1 548 000 or 1 inch to 25 miles

THACKERAY TOWNSHIP

Gold mineralization in west central Thackeray Township (Location Map) is spatially related to flow banded, quartz-phyric rhyodacitic flows in a sequence of massive to variolitic tholeiitic flows of the Kinojevis Group (Jensen 1982). Alteration, including silicification, hematization, sericitization, and pyritization, has affected black, iron tholeiites overlying the felsic metavolcanics. Pervasive silicification has imparted a saccharoidal texture and conchoidal fracture to the mafic flows; hematization has produced a mottled purple-mauve colour, and sericitization, a pale green-grey colour. Potassic alteration, which is superimposed on pervasive silicification, is centred about intersecting hairline fractures filled with quartz veinlets. Fine to very fine grained pyrite is both disseminated in the rock and concentrated along fractures, and can form 5% to 7% of the altered mafic flows. The area is cut by several narrow, conformable shear zones, which post-date alteration.

Metamorphism is upper greenschist facies; represented in garnet + epidote + carbonate veins. Garnet-epidote veins may be locally related to porphyritic syenite dikes which intrude the metavolcanics; this relationship was noted at the Murphy-Garrison Mine in Garrison Township (Cherry 1983).

HARKER TOWNSHIP

Detailed mapping of available outcrops was done in Harker Township (Location Map) to document the volcanic sequence and fault zones along which most of the known gold mineralization occurs (Satterly 1952a).

Mafic metavolcanics of the Kinojevis Group in Harker-Holloway Townships strike east-northeast and dip steeply south in a homoclinal succession. They consist of flows and fragmental rocks with minor amounts of grey-green chert. Tholeiitic flows are predominant near the base of the Kinojevis Group, with mafic fragmental units becoming more common towards the top of the section in southern Harker Township. Flows are massive, pillowed, porphyritic, and variolitic. Massive flows are very fine grained and equigranular; thick flows become medium grained equigranular with subophitic to ophitic texture. Pillowed flows consist of fine grained basalts with sparsely distributed siliceous interpillow fillings. They can be massive to porphyritic and variolitic. Some pillows have variolitic inner rims adjacent to their selvedges. Coalescing pin head varioles form 2 to 3 cm thick felsic rinds which disperse inwards to form individual varioles. Porphyritic flows are both massive and pillowed with 3 to 4 mm grey-white subhedral plagioclase phenocrysts, which are 10% to 12% of the individual flows and are evenly distributed throughout a flow.

Flow-top fragmental mafic volcanic rocks are most common in the upper part of the Kinojevis Group and form units up to 10 m thick. Fragments are angular and range from 0.5 to 30 cm in size, are cuspate in form, and constitute 80% or more of the fragmental units. In some, recognizable whole pillows or pillow fragments are present. Matrix material consists of aphanitic chlorite which weathers from grey-green to brown. Silica veinlets form a lacy network throughout the chloritic matrix. Silica veining is notably more prevalent in the permeable fragmental units than in the massive flow units. Later, crosscutting white quartz veins, up to 1 cm thick, are erratically distributed within fragmental units.

Towards the upper part of the Kinojevis Group in southernmost Harker Township, felsic metavolcanics occur as rhyolite units up to 15 m thick. These units are very fine grained and equigranular and locally exhibit pale to dark grey, 1 to 3 mm contorted flow banding. Some parts exhibit conchoidal fracture and very fine grained saccharoidal texture.

Chert beds, of limited extent, are present in the upper Kinojevis Group. Cherts are pale grey to grey-green and form 5 to 7 cm thick beds. In places, 1 to 2 mm laminae are present. Chert beds observed were consistently at the top of volcanic fragmental units with silica net veining in the matrix. The beds are contoured along the irregular top of the fragmental units and are overlain by massive flows. These chert beds occur as layers capping on silica-rich, porous mafic fragmental rocks in the Upper Kinojevis Group.

MINERALIZATION

All of the mineral occurrences examined within the Kinojevis Group appear to be related to zones of deformation and alteration. Alteration, involving silicification, carbonatization, and sulphidization, is confined spatially to shear zones. In some cases, alteration envelopes extend outwards from shear zones up to 1 or 2 m; however, the most intense alteration is consistently within shear zones.

Style of deformation is consistent throughout the section of the Kinojevis Group examined. Deformation involves planar brittle shear zones. Sparse evidence of ductile movement is usually limited to curviplanar deflection of earlier planar fabrics in the shear zone and indicates sinistral movement. Shear zones range from 30 cm to 1 m wide throughout southern and central Harker Township. Shear zone boundaries are sharply defined by the appearance of fissile chloritic cleavage. Host rocks may be massive to pillowed flows, with a change from undeformed to deformed rocks over a distance of 5 mm to 1 cm. Shear zone boundaries are typically abrupt, representing a brittle deformation environment. Brittle planar deformation is characteristic of shear zones proximal to and within the Destor Porcupine Fault Zone (DPFZ). However, in shear zones proximal to the DPFZ, the intensity of alteration and volume of rock which are affected by alteration, increase. In addition, hematitic alteration is present in the Consular-McDermott Fault Zone. In shear zones farther south of the DPFZ, scattered specularite occurs in late quartz veins and in syenite porphyries in shear zones. The following example illustrates features characteristic of brittle shear zones throughout the Kinojevis Group in Harker Township.

In southeast Harker Township, massive and fragmental mafic volcanic rocks are exposed near a 0.5 to 1.4 m wide shear zone. Contacts strike east-northeast and dip 75° to 80° south. The lower part of the exposed section consists of a massive, fine to medium grained, subophitic flow overlying mafic flow

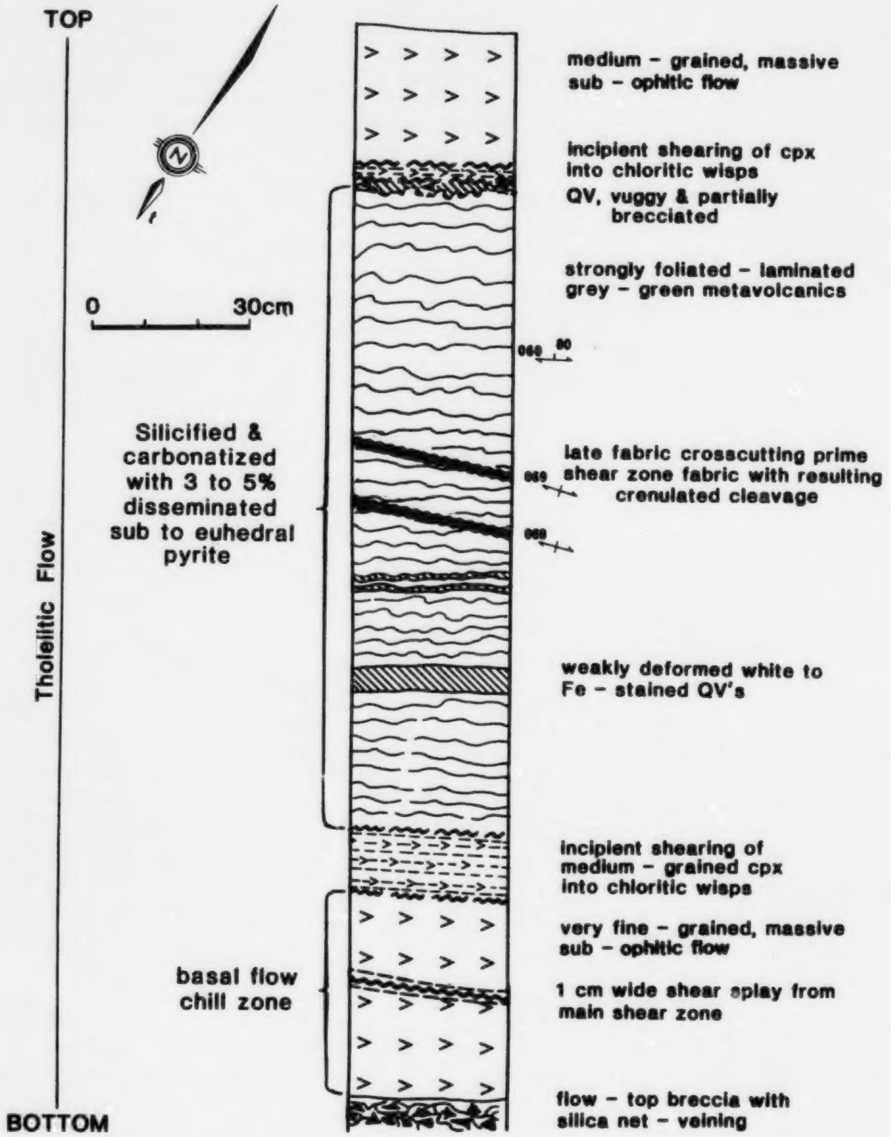
TOP
0
30cm
medium - grained, massive sub - ophitic flow
incipient shearing of cpx into chloritic wisps
QV, vuggy & partially brecciated
strongly foliated - laminated grey - green metavolcanics
068
80
Silicified & carbonatized with 3 to 5% disseminated sub to euhedral pyrite
late fabric crosscutting prime shear zone fabric with resulting crenulated cleavage
069
069
Tholeiitic Flow
weakly deformed white to Fe - stained QV's
incipient shearing of medium - grained cpx into chloritic wisps
very fine - grained, massive sub - ophitic flow
basal flow chill zone
1 cm wide shear splay from main shear zone
flow - top breccia with silica net - veining
BOTTOM

Figure 1. Plan view cross-section across near vertical, east-northeast striking shear zone cutting tholeiitic flows, Harker Township. (Project S59.)

top breccia. The upper part of this flow is vesicular. Vesicles increase to 5 mm in size and form up to 15% of the flow. In places they define a crude flow banding. Overlying the massive to vesicular flow rocks are fragmental flow top breccias and pillow breccia. Fragments are angular with pale alteration rinds. Complete pillows occur within the flow top breccia; and these are round (undeformed) to elongate (deformed). The host breccia is undeformed with a weak regional foliation best developed in the chloritic groundmass. Groundmass material is silicified and penetrated by a fine network of silica veinlets. The degree of silica veining increases towards the top of the fragmental unit where it is capped by another massive flow (Figure 1), which has a 30 to 40 cm, very fine grained lower chill zone. This rapidly grades into medium-grained subophitic tholeiite which is cut by sparse, late white quartz veins, 1 to 2 cm thick.

Shearing in this succession forms a sharply deformed zone, up to 1.4 m wide. The shear zone is localized along the base of the massive flow overlying the flow top breccia and is locally conformable to stratigraphy. Along strike, the shear zone does not follow the contact between breccia and massive flow base, but occurs approximately 0.5 m above this contact. Placement of the shear zone appears to be along a zone marking a change in grain size from very fine grained lower chill zone to a medium grained texture typical of the flow centre.

Alteration is confined to the shear zone and has no effect on rocks situated above and below. Carbonatization and silicification are pervasive, with variable amounts of very fine grained pyrite representing limited sulphidization (Figure 1). Within the shear zone, weak layering is defined by alternating pale grey and green layers with aphanitic texture. Shear zones are characterized by a prominent shear fabric paralleling shear zone contacts and, in places, well enough developed to impart a fissility to the deformed rocks. The development and rotation of dilational fabric among several shear zones consistently indicates sinistral movement.

Shear zones such as the one described here, and particularly those with more intense alteration, are the scenes of active gold exploration. The more favourable zones involve intense alteration within the shear zones, in addition to pervasive alteration of wallrocks. Hematization appears to accompany altered shear zones of higher grade gold mineralization such as the Consular-McDermott Zone.

ACKNOWLEDGMENTS

Field work was greatly enhanced by the assistance of D.M. Kingston in detailed work on individual occurrences. Discussions with company geologists from Barrick Resources Corporation, D.R. Bell Geological Services, Noranda's Ross Mine, and the St. Andrew Goldfields Mine are greatly appreciated. In addition, discussions with colleagues J. Malczak and D.G. Troop provided valuable information.

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S60. Preliminary Report on the St. Andrew Goldfields and Maude Lake Gold Deposits, District of Cochrane

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This project is part of Operation Black River-Matheson (BRIM) which was funded equally by the Ontario Ministry of Northern Affairs and Mines and the Ontario Ministry of Natural Resources

INTRODUCTION

Investigations of the St. Andrew Goldfields and Maude Lake gold deposits are part of the mineral deposits study initiated in the previous field season (Whittaker and Malczak 1984). Selected levels of the underground development at the St. Andrew Goldfields deposit were examined and sampled to provide more complete information on specific cross-sections studied in the previous season. A preliminary study of the Maude Lake gold deposit involved outcrop mapping and sampling. Documentation of the geology, alteration, structure and mineralization as well as petrographic and geochemical analyses of these deposits will contribute to the knowledge of gold deposits in the BRIM area.

ST. ANDREW GOLDFIELDS DEPOSIT

The St. Andrew Goldfields deposit occurs in the southcentral part of Stock Township and is serviced from a 1.5 km road which leads north from Highway 101, about 50 km east of Timmins (Figure 1). In 1972-1973, Quebec Sturgeon River Mines completed a drill program to test for mineralization along a section of the Destor Porcupine Fault Zone covered by 15 to 40 of overburden. Since 1983, St. Andrew Goldfields Limited has explored the zone of gold mineralization by development and drilling from four major levels and additional sublevels to a depth of about 225 m. A composite plan of the lateral workings covers a zone 500 m along and 225 m across the stratigraphic trend.

The deposit is situated immediately south of the Destor Porcupine Fault Zone, which marks the north boundary of the Stoughton-Roquemaure Group. In southern Stock Township, the fault zone trends east-northeast and exploration is restricted to a 250 m wide zone bounded to the south by a thick subparallel diabase dike. Both the dike and fault system dip steeply to the south. Rocks south of the diabase consist of relatively unaltered mafic metavolcanics. The sequence enclosed between the fault and the diabase essentially consists of altered mafic volcanic flows, strongly altered and veined mafic and ultramafic (fuchsite-rich) rocks, variably altered felsic dikes, and minor late stage mafic dikes. Gold mineralization occurs in elongate zones within an east-northeast trending wedge or keel of massive and pillowed mafic metavolcanics up to about 100 m wide. In turn, this wedge is surrounded by a thicker, more extensive, interlayered complex of highly altered and veined mafic and fuchsite-rich rocks.

Drill holes through the Destor Porcupine Fault Zone intersect a system of chlorite and talc-chlorite shear zones over a width of up to approximately 150 m. Locally, the zone branches and its overall form is a strongly undulating east-northeast trending surface dipping about 50°-70° south. A cross-cut through a branch of the fault system on the 575′ level passes through about 10 m of highly schistose chlorite and talc-chlorite rock with three parallel fault gouge zones 30 cm to 50 cm wide. The fault gouge consists of a dark green, greasy textured, pliable material which includes talc and possibly chlorite and serpentine.

The main mineralized zones occur within an east-northeast trending vertical wedge or keel of massive and pillowed mafic metavolcanics up to

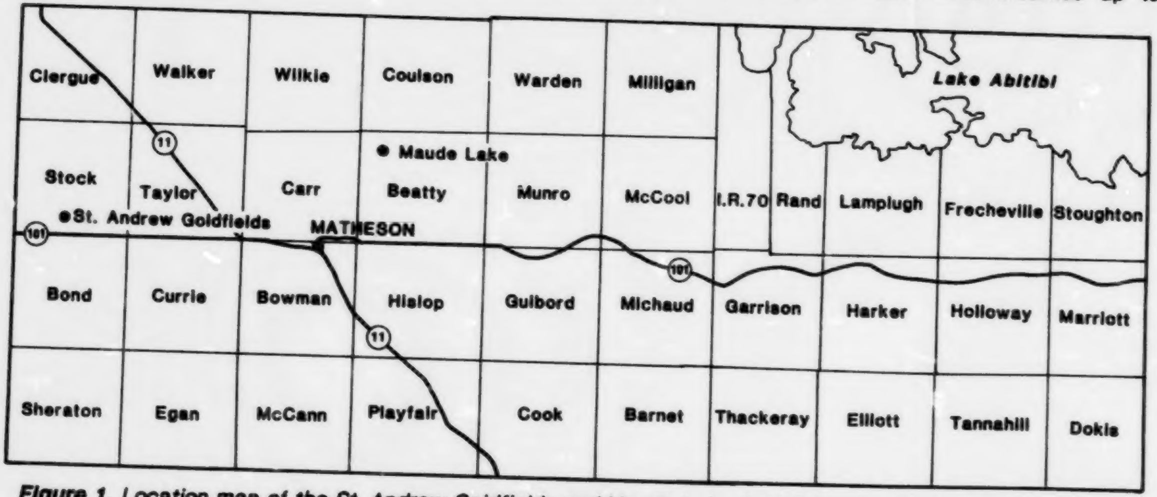

Figure 1. Location map of the St. Andrew Goldfields and Maude Lake Gold Deposits. (Project S60.)

about 100 m wide. Pillow forms observed on the backs of the drifts are flattened with an aspect ratio of at least 10:1. Selvedges are generally 1-2 cm thick and many pillows have variolitic centres. The long axes of the pillows are oriented east-northeast and dip vertically. Parallel zones within this unit are sericitized to varying degrees indicated by a colour variation from dark green to buff brown. The most strongly sericitized zones have no recognizable varioles but chlorite rich pillow selvedges are usually preserved. All mafic metavolcanics are strongly foliated and fine grained. Irregular, tightly folded veinlets of quartz and carbonate form up to 20% of the rocks. The host material also contains up to 5% finely disseminated pyrite.

The wedge of mafic metavolcanics is surrounded by a thicker, more extensive, interlayered complex of highly altered and veined mafic and fuchsite-rich rocks. These rock units are typically massive to foliated and medium grained, with a groundmass of chlorite, carbonate, and sericite or fuchsite. They host an extensive network of highly distorted carbonate and few quartz veinlets which comprise up to 40% of the rock. The widely variable fuchsite content of these units locally allows distinction between units of mottled grey and green coloured varieties.

All rock units within the altered sequence are cut by a system of strongly altered felsic dikes. They are light brown-grey, massive, fine- to medium-grained rocks which are highly silicified and commonly sericitized and carbonatized. The dikes host a network of quartz and carbonate veinlets (up to 20%) and contain 5% to 20% fine-grained, disseminated euhedral pyrite.

An extensive, vertical, east trending band of strongly foliated chlorite, carbonate, and quartz, 5 m to 40 m wide, passes obliquely through all major rock units. It is essentially a chlorite schist with about 60% irregular, strongly folded and brecciated veinlets of carbonate and quartz. The zone converges with the Destor Porcupine Fault Zone to the west of the underground workings.

Few narrow, (<40 cm) dark green, fine grained, massive mafic dikes represent the last intrusive phase. These dikes are usually steeply dipping and planar; locally they are offset and sheared. All other lithologic units are strongly fractured and most contacts between major units are fault bounded.

The main mineralized zones occur within sections of the central wedge of mafic metavolcanics which have undergone a high degree of sericitization. The mineralization is associated with parallel quartz vein systems which form a linear zone oriented about 240°/40°. It subcrops near the shaft and tapers off at the western part of the tested zone, a total distance of at least 250 m. Individual mineralized veins are up to 1 m wide and consist of massive, coarse-grained grey-white quartz with about 5% finely disseminated pyrite, gold and minor chalcopyrite and arsenopyrite. Free gold forms distinct, irregular grains (up to 1.0 mm) or fine, microfracture fillings. It occurs within and along the boundaries of fine-grained, inclusion rich pyrite and is in contact with fine, irregular chalcopyrite grains and occasionally, fine-grained euhedral arsenopyrite. Fine, disseminated pyrite within the adjacent rocks also contains gold. In addition, a number of strongly altered felsic dikes throughout the explored sequence, contain up to 10% finely disseminated pyrite with anomalous gold values. Reported grades and tonnages are 525 626 tons at 0.168 ounce gold per ton or 735 625 tons at 0.135 ounce gold per ton (The Northern Miner, July 18, 1985).

The third and fourth levels of the deposit were examined and sampled by the author to provide information on the geological setting of the mineralized zones sampled in 1984 (Whittaker and Malczak 1984).

MAUDE LAKE GOLD DEPOSIT

The Maude Lake gold deposit is situated in the northwest corner of Beatty Township (Figure 1). It occurs within the Stoughton-Roquemaure Group of mafic metavolcanics. The deposit is exposed in a pit excavated through more than 15 m of varved clays. Rock surfaces are exposed over a roughly rectangular area, approximately 170 m by 60 m (Figure 2). Most of the outcrops consist of undeformed north to northeast facing, steeply dipping, mafic pillowed flows, and pillow breccias. In localities, pillows have one or a parallel set of elongate drain-away lenses or "eyebrow" structures which parallel the general orientation of the flows (Wells *et al.* 1979). These lenses, and locally zones interstitial to the pillows, are filled with either black chert or coarse white quartz and carbonate. At the west end of the area, conformable with the pillowed flows, there is a series of flow breccias up to 2 m wide, trending about 125° and dipping steeply to the northeast. In the northeast corner of the pit, there is a conformable massive pyrite zone up to 1 m thick. This zone grades from pillowed flows with pyritic selvedges at the base to a massive coarse pyritic zone. The pyrite zone is in contact with a large, northwest trending, steeply dipping peridotite dike or sill which marks the eastern extent of the mineralized zone exposed in the pit. The boundary of the peridotite contains irregular carbonate veinlets which are generally aligned with a contact foliation. This zone is more intensely foliated and banded immediately next to the pyrite zone, and may represent either a narrow (<1 m) tuff or an argillaceous unit; the strong foliation (lamination) however is induced tectonically. Irregular, east trending, steeply dipping diorite and feldspar porphyry dikes intrude the metavolcanics in the central and western parts of the pit. These dikes are a mottled grey colour and composed of a massive fine-to medium-grained aggregate of feldspar, 15-20% biotite and chlorite and 5% finely disseminated euhedral pyrite. Two north trending diabase dikes intrude the mafic metavolcanics in the west and central part of the pit area.

The mafic metavolcanics contain variable percentages of carbonate and sericite except in parts of the north and south extremities of the pit area. Weathered surfaces of sericitized mafic metavolcanic flows are a light grey to buff colour with sericite or green mica on foliation and fracture planes. The carbonatized zone is slightly less extensive and overprints the sericitized zone. This zone, marked by

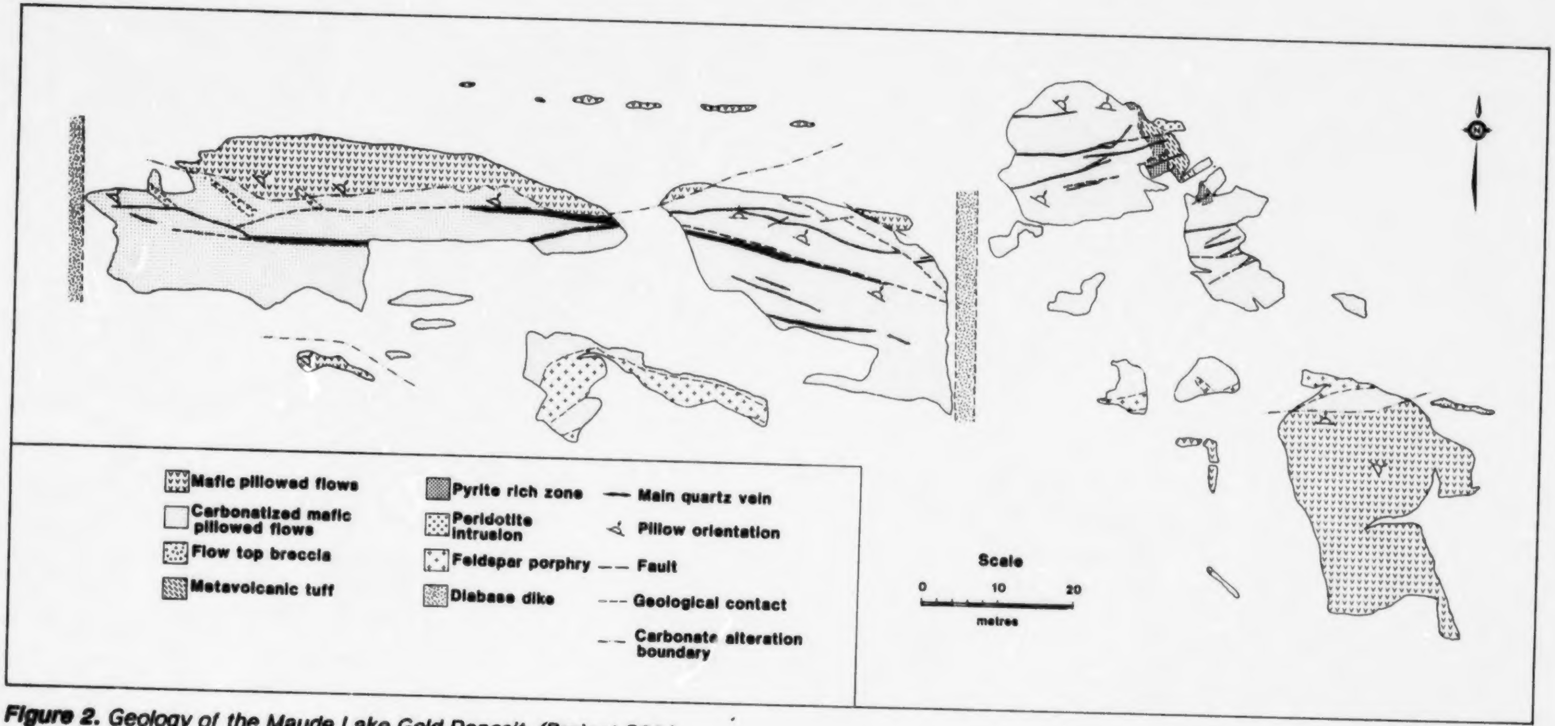
N
Mafic pillowed flows
Carbonatized mafic pillowed flows
Flow top breccia
Metavolcanic tuff
Pyrite rich zone
Peridotite intrusion
Feldspar porphry
Diabase dike
Main quartz vein
Pillow orientation
Fault
Geological contact
Carbonate alteration boundary
Scale
0
10
20
metres

Figure 2. Geology of the Maude Lake Gold Deposit. (Project S60.)

rusty brown weathered surfaces widens from about 20 m in the west to 45 m in the east.

Gold mineralization is associated with an east trending, steeply dipping quartz and quartz-carbonate vein system concentrated within the strongly carbonatized and sericitized mafic flows. Individual veins range in width from less than 1 cm to more than 1 m. They are composed of massive, medium- to coarse-grained, blue-grey quartz and lesser white to grey granular ferroan dolomite or other iron carbonates. Veins contain up to 5% finely disseminated pyrite and minor visible gold, sphalerite and arsenopyrite. Finely disseminated pyrite within the host volcanic rocks may also carry gold. Gold content varies locally, with bulk grades ranging from about 0.12 ounce per ton in the west zone to >0.35 ounce per ton in the east area (R.A. Bennett, Project Geologist, Maude Lake Gold Mines Limited, personal communication, 1985). The major veins are associated with shear or fault zones, several of which cause sinistral displacement of the massive pyrite zone at the east end of the exposure. Individual offsets are typically less than 2 m and the veins pinch out at the edge of the peridotite contact. Two late stage, low angle shear zones at 140°/40°S and 105°/40°S offset the mineralized veins in one locality. Drill results indicate that the mineralized system continues to a depth of at least 200 m and is offset in places (R.A. Bennett, Project Geologist, Maude Lake Gold Mines Limited, personal communication, 1984, 1985).

Samples of mineralized veins and variably altered rock units were collected throughout the deposit for petrographic study and geochemical analysis.

ACKNOWLEDGMENTS

The following personnel were very helpful in facilitating access to and providing additional information on currently developing mineral deposits: Mr. D. Bryant, Mine Manager, Mr. O. Zavesiczky, Mine Geologist, and Miss D. Gerth, Geologist, St. Andrew Goldfields Limited and Mr. R.A. Bennett, Project Geologist, Maude Lake Gold Mines Limited. Field studies were carried out with the able assistance of Dave Kingston.

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S61. Preliminary Report on Geology and Metasomatism at the Ross Mine and Vicinity, District of Cochrane

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This project is part of Operation Black River-Matheson (BRIM) which was funded equally by the Ontario Ministry of Northern Affairs and Mines and the Ontario Ministry of Natural Resources.

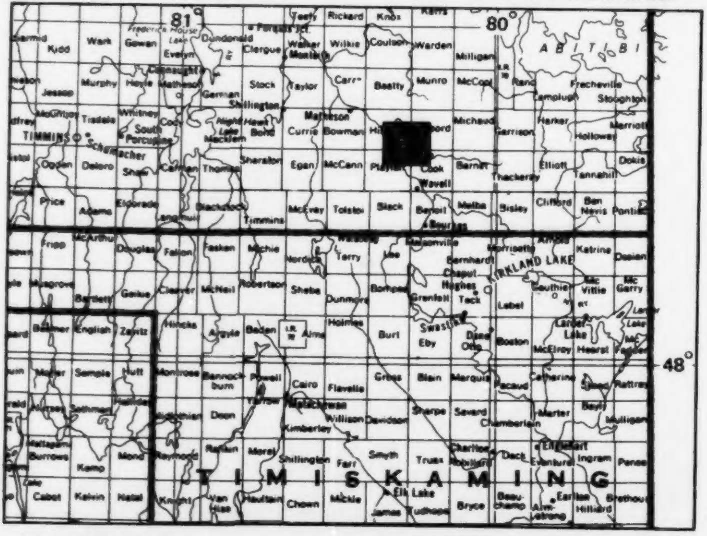
INTRODUCTION

The Ross gold-silver(-copper) deposit is located along the southeast corner of Hislop Township, approximately 700 m north of the Holtyre townsite and 9.5 km from Ramore via Highway 572. The mine, which has been in continuous production since 1935, was originally owned and operated by Hollinger Consolidated Gold Mines, but was acquired by Pamour Porcupine Mines Limited in 1976. The early history and development of the Ross Mine is reported by Moore (1937). Currently, active workings extend from the 150-foot level down to the 3150-foot level, serviced by a three-compartment shaft, with ore being hoisted from loading pockets at the 1500 and 3000-foot levels. The principal mining method has been shrinking stoping, and more recently, longhole ITH-blasted vertical cave retreat stoping. An average of about 400 tons of ore is hoisted per day and trucked to Timmins for milling. The original Ross mill was dismantled subsequent to the Pamour takeover of the mine. In total, the mine has produced approximately 900 000 ounces of gold, and 1 330 000 ounces of silver, averaging 0.169 ounce Au per ton, and 0.283 ounce Ag per ton, (Ploeger 1978) over its history.

Several published reports on the geology and ore controls at the Ross Mine exist, the most notable being those of Jones (1948), Prest (1957), and Akande (1982). These studies and geological reports of the Hislop/Guibord Townships vicinity (Prest 1953, 1957) have produced considerable controversy over the nature of lithologies in the mine area and their relationship to gold mineralization. However, most workers agree that lithologies in the vicinity of the Ross Mine have suffered considerable metasomatic alteration. It is not clear whether the mine stratigraphic unit is represented by true felsic fragmental volcanic rocks or by highly altered basaltic rocks, in view of the fact that the area is the locus of such intense metasomatism, deformation, and precious metal mineralization. Relative lack of outcrop in the vicinity hampers stratigraphic correlation. Similar, less intense alteration in mafic volcanic rocks intruded by a syenite plug at the Kelore Deposit (Prest 1957), about 2 km north of the Ross Mine, provideS some field evidence of metasomatic bulk compositional changes.

The documentation of the geology of the Ross Mine forms a major component of this study. In addition, three critical problems, which this project is intended to address and resolve, are as follows:

1. The development of a chemostratigraphic model for the area to determine if the Ross Mine occurs near the top of a major volcanic cycle (MERQ-OGS 1983), or if intense alteration has obscured normal petrochemical evolution within a single volcanic sequence.
2. The determination of the amount of chemical alteration imposed on the highly altered rocks in the mine area, and a probable sequence of mineral reactions necessary to produce the observed assemblages from a postulated precursor.
3. The paragenesis of various periods of alteration and their relationship to the major periods of deformation, veining, and gold and sulphide deposition in the mine area.



LOCATION MAP Scale: 1:1 584 000 or 1 inch to 25 miles

REGIONAL GEOLOGY

Recent mapping along the Destor-Porcupine complex (DPC) to the north of the Ross Mine (Trowell 1982; Trowell and Johnstone 1983; Johnstone and Trowell 1984) and through the Ramore area (Jensen 1974, 1975), have helped to establish a basic stratigraphy for this area. The DPC is a major east-west trending structural break characterized by intense deformation, displacement, and possible truncation of stratigraphic units. The Stoughton-Roquemaure Group, dominated by ultramafic flows and layered sills intercalated with mafic rocks, has been mapped in detail through Beatty and Munro Townships (Johnstone and Trowell 1984), north of the Ross Mine, and is generally found north of the DPC, progressing to the east. To the south of the Ross Mine, in Playfair and Cook Townships, Jensen (1974, 1975) has mapped the iron to magnesium tholeiitic sequence of the stratigraphically higher Kinojevis Group. The suggestion (MERQ-OGS 1983) that the Stoughton-Roquemaure/Kinojevis boundary transgresses the DPC in Hislop Township is largely made on the basis of a felsic tuff to agglomerate unit which has been traced in sparse outcrops from the west through Bowman and Hislop Townships. This unit, presumed to be the uppermost stage of the Stoughton-Roquemaure Group, is extended through the Ross Mine area (Figure 1), necessitating a change in regional strike, which may be explained by rotational displacement along the northwest-trending Hislop Fault, a crossfault off the DPC. Timiskaming-type metasedimentary rocks, which occur south of the mine and west of this fault (Prest 1953, 1957; Jensen 1974, 1975), have possibly accumulated in an ancient graben-like trough.

MINE GEOLOGY

LITHOLOGY

Previous workers have identified felsic fragmental rocks in the mine workings (Jones 1948; Prest 1957) despite the fact that most rocks in the area have been subjected to a high degree of alteration, recrystallization, and fracturing and silica flooding. While there are some local units which do appear to be true volcanic fragmentals and fine to coarse turbiditic sediments, they are not prevalent. Mapping appears to have been conducted largely on the basis of colour, with green mottled (chloritic) rocks being assigned to a basalt-andesite unit and buff yellow (sericitic) rocks to the dacitic felsic pyroclastic unit. Because of relative differences in the modal mineralogy of these rocks and their behaviour during deformation, many of the sericitic rocks do indeed have a pseudo-fragmental or porphyritic appearance, probably caused by explosive hydraulic brecciation and recrystallization. Conversely, the mafic rocks have taken on a characteristic fracture pattern termed 'plymouth rock', in which original conjugate cleavages in the rock have dilated during deformation and filled with quartz-calcite-anhydrite aggregates. This texture may in places be traced across mineralogical transitions and therefore implies that the apparent bulk compositional shifts are not due to lithological contacts but rather alteration gradients. Thus, there are virtually no lithologic units which may be mapped for any great distance. Ore has been found in most lithological variants in the mine.

The only possible intrusive units identified thus far in the mine area are fine-grained, purple to buff dikes believed to be lamprophyre. Generally no more than 2 m in width, these dikes are heavily carbonatized and bear 1 mm biotite crystals. In the northern part of the mine, one of these dikes swells to 10 m, and crosscuts an ore zone.

ALTERATION

The rocks in the vicinity of the Ross Mine must have been subjected to multiple stages of intense alteration, in order to account for the strongly overprinted nature of observed mineral assemblages. Alteration types identified by previous workers (Prest 1957; Ploeger 1978; Akande 1982) and confirmed during this study, listed in order of approximate intensity, are:

1. sericitization
2. carbonatization
3. silicification
4. chloritization
5. hematization
6. feldspathization
7. anhydritization
8. pyritization
9. epidotization

Locally, fine-grained, pink-red rocks in the mine have been mapped as syenites by Jones (1948), Prest (1957), and Akande (1982); however, the gradational nature of the contacts (alteration gradients, as discussed previously) suggests that these rocks may in fact be highly silicified basalts, as was first suggested by Ploeger (1978). The intrusive appearance may be attributable to a high degree of impregnation by fine hematite and anhydrite aggregates, a hypothesis which may be supported by petrographic and rock geochemical studies to follow.

While there is a general association of intense sericite (phengite) and carbonate (ankerite-ferroan dolomite) alteration, plus silica flooding, within mineralized zones, ore has been found associated with all the aforementioned alteration types. This lack of correlation is best explained by a history of metasomatic changes in these rocks occurring pre-, syn-, and post-mineralization. In addition to alteration induced by gold-bearing hydrothermal fluids; diagenetic and burial metamorphic reactions, prograde-retrograde regional metamorphism, and seawater-dominated hydrothermal circulation also may have been responsible to some extent for chemical and mineralogical changes.

STRUCTURE, ORE ZONE CONFIGURATION AND MINERALIZATION

The structural style in the mine area can best be summarized as strong east-west to northwest-southeast shearing, cut by later north-south brittle faulting. The shear fabric is generally a foliation parallel with the overall strike of the rocks. These shear zones can run along the margins or cores of vein systems,

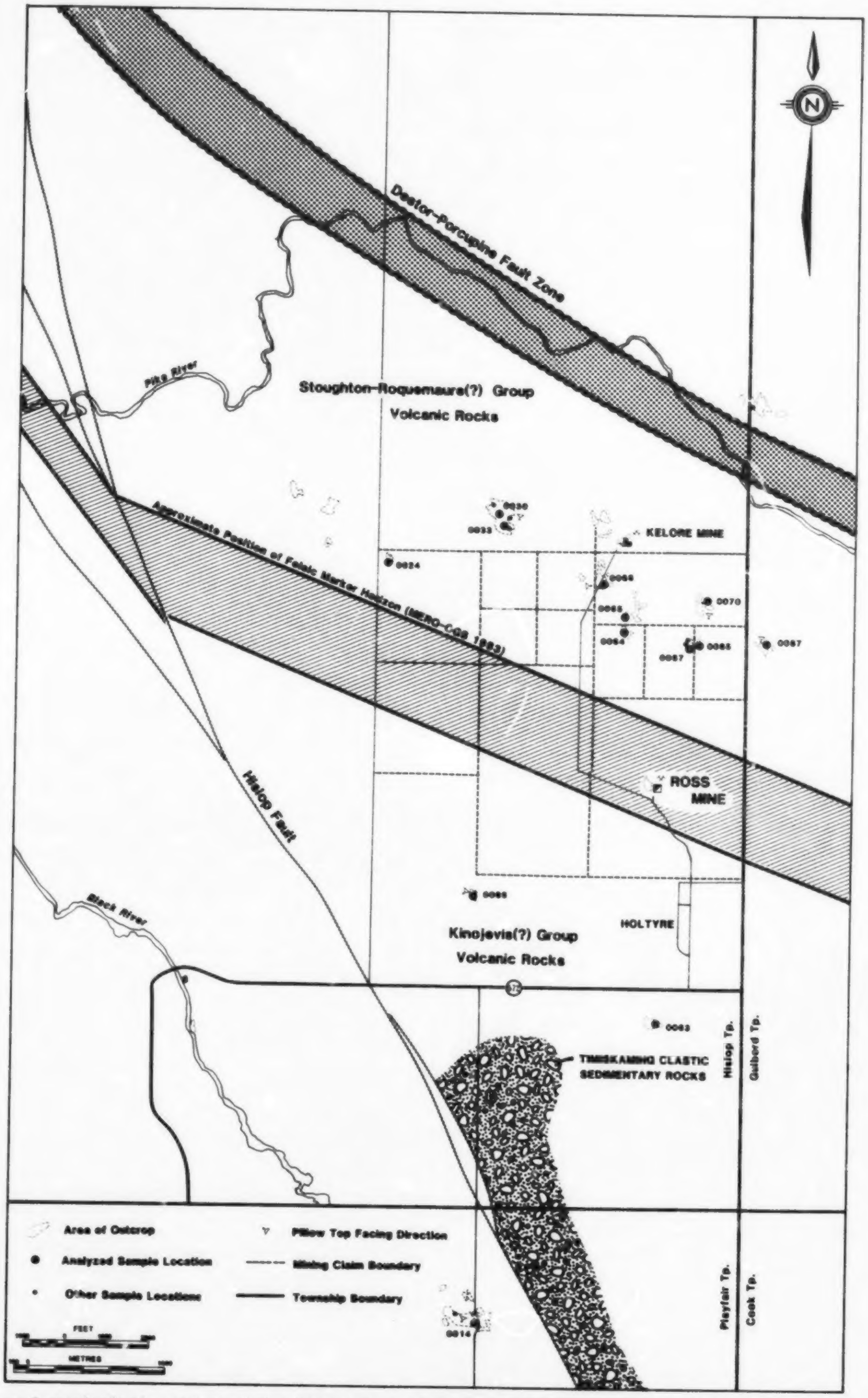

N
Destor-Porcupine Fault Zone
Pike River
Stoughton-Roquemaure(?) Group
Volcanic Rocks
0030
0033
KELORE MINE
0024
Approximate Position of Felsic Marker Horizon (MERQ-OGS 1983)
0066
0070
0065
0064
0067
0085
0087
ROSS
MINE
Hislop Fault
Black River
0088
HOLTYRE
Kinojevis(?) Group
Volcanic Rocks
0083
TIMISKAMING CLASTIC
SEDIMENTARY ROCKS
Hislop Tp.
Guibord Tp.
Playfair Tp.
Cook Tp.
0014
Area of Outcrop
Analyzed Sample Location
Other Sample Locations
Pillow Top Facing Direction
Mining Claim Boundary
Township Boundary
FEET
METRES

Figure 1. Local geological setting of the Ross Mine showing major structural and lithological elements in the area (after Prest 1956, and MERQ-OGS 1983). Outcrop areas studied and sampled for analysis are shown. (Project S61.)

or act as emplacement sites for discrete narrow mineralized quartz veins. The late brittle faults are primarily dip slip, as indicated by stretching lineations, and they truncate mineralized zones and alteration styles. Lamprophyre dikes, which parallel the shears, are also truncated by brittle faults. Prest (1957) indicates that while tight fold structures are almost certainly present in the mine area, the lack of traceable units precludes their identification.

The ore zones occur primarily as two distinct types:

1. Roughly cylindrical to ellipsoidal, steeply west-dipping, extensive vein networks within a heavily brecciated and altered zone, somewhat like pipe-structures (e.g. 2/2B, 10, 12, and 18/18B vein systems). The networks are characterized by sub-parallel, *en echelon*, blue-grey quartz veinlets, termed 'A' stringers. Some of these pipes, like the 2/2B system, can be traced from surface down to the 3150-foot level, where the plan section of the zone changes from roughly circular to elongate (Figure 2). This reflects a change from bounding shears on the upper levels, to localization of the ore zone within shears on the lower levels.
2. Steeply dipping, narrow, white quartz (-carbonate) veins localized in the cores of northwest-trending shears and found primarily on the upper levels of the mine (e.g. 4/5, 7, 8/8A, 13, and 14 veins). These 'B' veins occur adjacent to heavily brecciated and sheared rock. The 1 vein is somewhat unusual in that it combines both 'A' stringer and 'B' vein types of mineralization, and has an inconsistent attitude (Figure 2). Unmineralized late quartz 'C' veins are emplaced along sub-horizontal joint sets.

The blue-grey 'A' stringers, which are common in the mine workings and not always gold-bearing, appear associated with pyrite and chalcopyrite in ore shoots. Akande (1982) also reports bornite, tennantite, and sphalerite, generally rimming chalcopyrite; the location of the gold is unknown. The massive 'B' veins are characterized by heavy sulphide concentrations of pyrite, chalcopyrite, sphalerite, galena, argentite, and tennantite, plus pearcite, proustite, native gold, and electrum (Akande 1982). The occurrence of silver minerals is quite unusual to Archean gold deposits, as is the deposit Au:Ag ratio of 1:1.94 (LaRocque 1952). Often, 'A' stringers appear to have been re-opened and injected with 'B' vein material, where the best grades are observed. The 'C' veins contain some remobilized sulphide ores, notably tennantite and galena.

FIELD PROGRAM AND PROPOSED STUDY

Field work has concentrated on detailed underground mapping and sampling in the vicinity of several of the major vein systems at the Ross Mine. Additionally, regional reconnaissance mapping and sampling in the area surrounding the mine have been undertaken in order to provide data on unaltered equivalent rocks, relative to the mine environment (Figure 1). Fourteen regional samples have already been selected and submitted for analysis. Additional samples will be analyzed from the mine sampling program.

Many of the underground samples have been chosen for their proximity to, and yet lack of, vein mineralization; also, paired samples have been chosen progressively away from vein contacts. Sample size and homogeneity parameters have been carefully adhered to during the program. Vertical and lateral sampling has been completed in the following main pipe-like orebodies: 1 vein, 2/2B vein, 10/12 veins, 18/18B vein.

Additionally, wallrocks from the following narrow veins have been sampled: 4/5 vein, 7 vein, 8A vein, 11 vein, and 13/14 vein.

Natural chemical variation of volcanic magma series is well documented (Irvine and Baragar 1971) and forms the basis of most chemostratigraphic studies. The numerous chemical analyses available for this area from the work of Jensen (1974, 1975), Trowell and Johnstone (1983), and Johnstone and Trowell (1984) can be used, with the aid of computer reduction, to provide a range of compositional variation into which the regional and mine analyses of this study should fall (Pearce 1968). Therefore, departures from expected curves and elemental ratios may be caused by metasomatism, the correction of which may be achieved through the methods of Beswick and Soucie (1978), or Gresens (1967). Computer programs for the solution of mass balance and elemental ratio equations have been written by the author.

Another method for determining the metasomatic changes and alteration sequence, particularly for the highly altered mine rocks, involves the use of alteration norms. A computer program has been written which expands upon the epinorm (Barth 1959) for metamorphic rocks, to provide a unique solution of modes of expected mineral phases. This is essentially a problem of simultaneous linear equations in which the unknowns are the modes, and the equations are mineral reactions and stoichiometries. The value of this procedure lies in ascribing various chemical changes in these rocks, which may be fixed by trace element ratios or mass balance calculations, to actual mineral reactions. These reactions should be supported by petrographic evidence. In this way, it may be possible to separate the alterations directly associated with gold enrichment from background metasomatism.

ACKNOWLEDGMENTS

The author wishes to extend his thanks to the staff of Pamour Porcupine Mines Limited, Ross Division, who made possible the underground portion of this project. In particular, geologists Hugh Lockwood and Paul Baleck are acknowledged for their efforts towards my understanding of some of the complexities of the Ross Mine. Drs. M.E. Cherry and P.J. Whittaker of the Ontario Geological Survey are thanked for their helpful discussions.

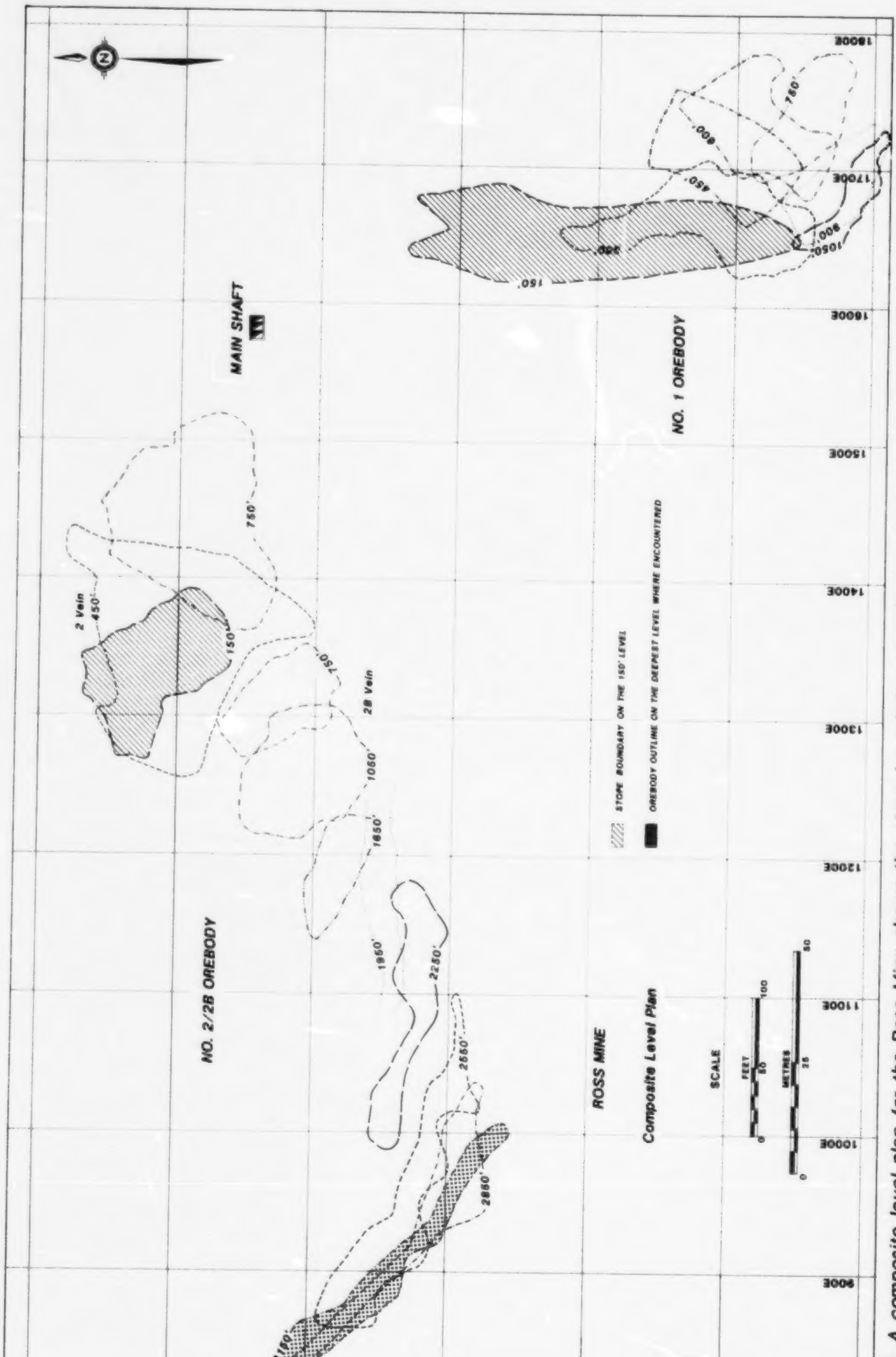

N
MAIN SHAFT
NO. 1 OREBODY
NO. 2/2B OREBODY
2 Vein
2B Vein
150'
450'
600'
750'
900'
1050'
1650'
1950'
2250'
2550'
2860'
3160'
ROSS MINE
Composite Level Plan
SCALE
FEET 0 50 100
METRES 0 25 50
STOPE BOUNDARY ON THE 150' LEVEL
OREBODY OUTLINE ON THE DEEPEST LEVEL WHERE ENCOUNTERED
2300N
2200N
2100N
2000N
1900N
1800N
1700N
9000E
10000E
11000E
12000E
13000E
14000E
15000E
16000E
17000E
18000E

Figure 2. A composite level plan for the Ross Mine shows the stope boundaries or orebody outlines for the No. 1 and No. 2/2B orebodies throughout selected levels of the mine, with respect to the mine grid system and the main shaft. Note the decreasing size and irregular orientation of the No. 1 orebody and the change in shape of the No. 2/2B orebody, from roughly circular on the upper levels to elongate on the deeper levels. The orientation of the latter is similar to that of the narrow vein systems on the upper levels. (Project S61.)

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S62. Industrial Mineral Potential of the Black River-Matheson (BRIM) Area, District of Cochrane

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This project is part of Operation Black River-Matheson (BRIM) which was funded equally by the Ontario Ministry of Northern Affairs and Mines and the Ontario Ministry of Natural Resources.

INTRODUCTION

Mineral deposits studies within the Black River-Matheson (BRIM) area, begun in 1984 (Whittaker and Malczak 1984), include an assessment of the industrial mineral potential. The most significant possible sources of industrial minerals within the area, excluding asbestos, are: serpentine filler minerals from the Hedman Mine in Warden Township; alkali feldspar flux minerals from a hornblende syenite phase of an intrusion in Egan Township, talc-magnesite from a peripheral zone at the former Johns-Manville Munro Asbestos Mine in Munro Township, and monument/facing stone from the Garrison stock in Garrison Township. In addition, there is ample rock suitable for crushed stone, particularly in Munro and Harker Townships (Figure 1). Commodities considered initially but not found within the area include marl, barite, residual kaolinite, and pegmatite deposits (rare earth, lithium, beryllium, zirconium, and fluorine-bearing minerals).

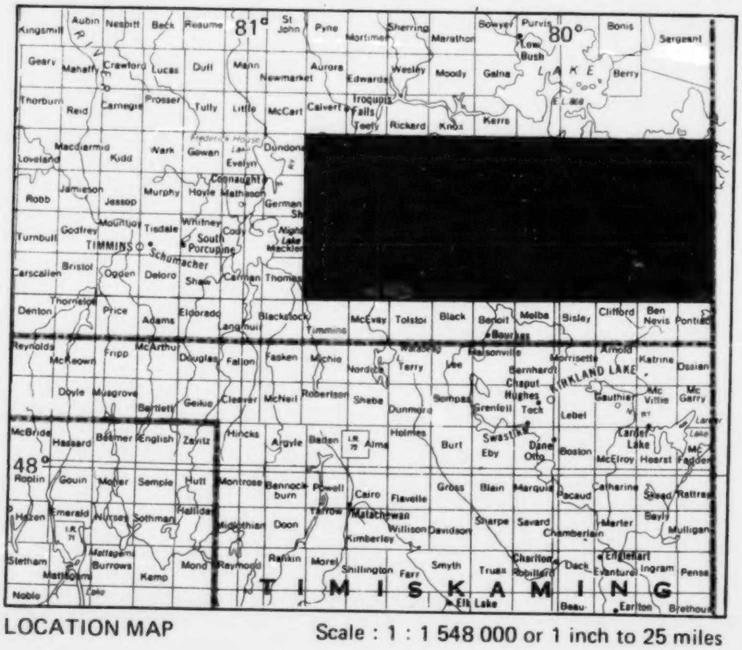
SERPENTINE FILLER MINERALS

The Hedman Mine in Warden Township is the only actively producing industrial mineral deposit within the BRIM area. It occurs within a serpentinized dunite or peridotite at the northern boundary of the east-trending, steeply dipping Munro-Warden ultramafic complex (Arndt 1975, p.20). Traverses near the deposit indicated that the ultramafic unit is bounded to the north by mafic pillowed flows, with minor felsic metavolcanic units, and to the south by a wedge of brecciated mafic metavolcanics and layered peridotite, pyroxenite, and gabbro sills. Although no contacts were observed, in one locality, outcrops of strongly foliated serpentinized dunite occur about 15 m north of an outcrop of "knobby" peridotite, possibly indicating a sheared or fault contact to the south. North-trending Matachewan diabase dikes crosscut the entire succession.

The serpentinized dunite has a strike length of at least 1 km west of the open pit. The dunite is exposed over a width of at least 150 m and has been drilled to a depth of 225 m. Total reserves are estimated at 40 million tons (J.J. Mangan, President, Hedman Resources Limited, personal communication, 1984). The serpentinized dunite is relatively homogeneous and consists of massive lizardite with veinlets of magnetite and chrysotile. A few narrow rodingite dikes occur within the pit area. A detailed description of the serpentinite, serpentine filler and its uses is given by Whittaker and Malczak (1984).

FLUX MINERALS

There is potential for a large supply of flux minerals, specifically alkali feldspars, from a hornblende syenite phase of an intrusion within Egan Township. The intrusion is irregular in form and covers an area of at least 25 km^2 in central Egan Township (Pyke *et al.* 1972), where it intrudes Kinojevis Group metavolcanics.


81°
80°
48°
Kingsmill
Aubin
Nesbitt
Beck
Reaume
St John
Pyne
Sherring
Mortimer
Marathon
Bowyer
Purvis
Bonis
Sargeant
Geary
Mahaffy
Crawford
Lucas
Dull
Mann
Newmarket
Aurora
Edwards
Wesley
Moody
Galna
Low Bush
LAKE
Berry
Thorburn
Reid
Carnegie
Prosser
Tully
Little
McCart
Calvert
Iroquois Falls
Teefy
Richard
Knox
Kerrs
Loveland
Macdiarmid
Kidd
Wark
Gowan
Frederick House Lake
Evelyn
Dundonald
Connaught
Robb
Jamieson
Jessop
Murphy
Hoyle
Matheson
German
Turnbull
Godfrey
Mountjoy
Tisdale
Whitney
South Porcupine
Cody
Night Hawk Lake
Mackle
TIMMINS
Schumacher
Carscallen
Bristol
Ogden
Deloro
Shaw
Carman
Thomas
Denton
Thorneloe
Price
Adams
Eldorado
Langmuir
Blackstock
Timmins
McCvay
Tolstoi
Black
Benoit
Melba
Bisley
Clifford
Ben Nevis
Pontiac
Reynolds
McKeown
Fripp
McArthur
Douglas
Fallon
Fasken
Michie
Nordica
Terry
Lee
Maisonville
Morrisette
Arnold
Katrine
Ossian
Doyle
Musgrove
Bartlett
Geikie
Cleaver
McNeil
Robertson
Sheba
Dunmore
Sempas
Bernhardt
Chaput Hughes
Grenfell
Teck
KIRKLAND LAKE
Lebel
Gauthier
Mc Vittie
Mc Garry
McBride
Hassard
Beemer
English
Zavitz
Hincks
Argyle
Baden
Alma
Holmes
Burt
Swastika
Eby
Otto
Boston
Larder Lake
McElroy
Hearst
McFadden
Roplin
Gouin
Mosher
Semple
Hutt
Montrose
Bannockburn
Powell
Cairo
Flavelle
Gross
Blain
Marquis
Pacaud
Catharine
Skead
Rattray
Hazen
Emerald
Nursey
Sothman
Halliday
Midlothian
Doon
Yarrow
Matachewan
Willison
Davidson
Sharpe
Savard
Chamberlain
Marter
Bayly
Mulligan
Kimberley
Stetham
Mattagami
Burrows
Kemp
Mond
Raymond
Rankin
Morel
Shillington
Farr
Smyth
Truax
Charlton
Robillard
Dack
Englehart
Evanturel
Ingram
Pense
Noble
Elk Lake
Beauchamp
Earlton
Brethour
TIMISKAMING

LOCATION MAP

Scale : 1 : 1 548 000 or 1 inch to 25 miles

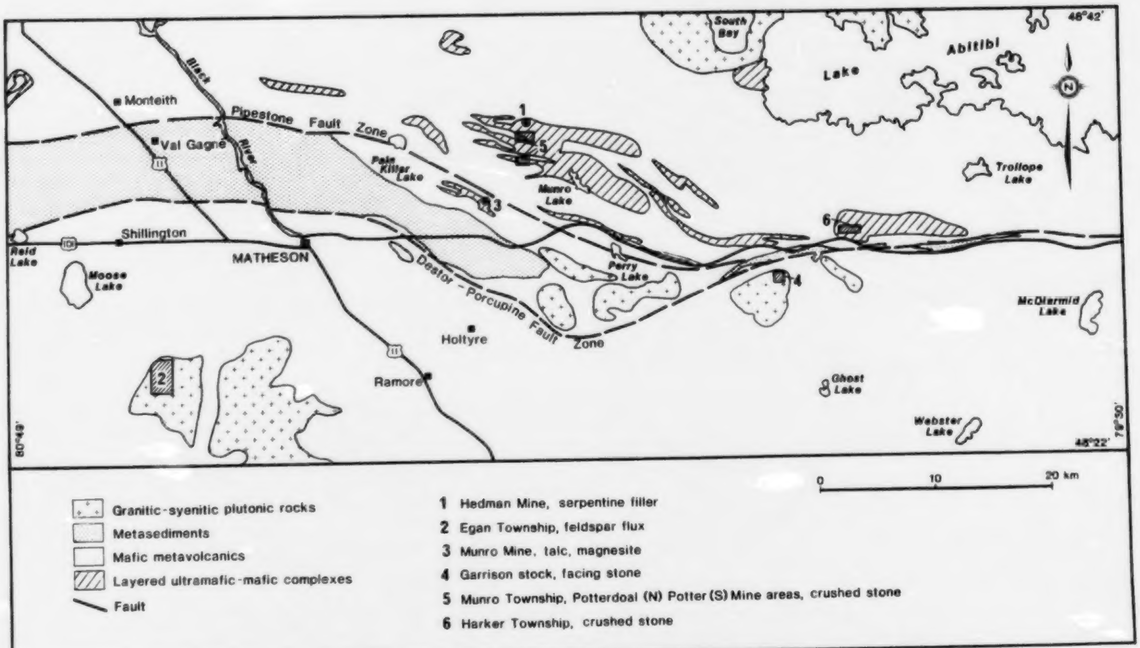

South Bay
Abitibi
Lake
48°42'
Monteith
Val Gagne
Black River
Pipestone Fault Zone
Pelo Killer Lake
Munro Lake
Trollope Lake
Shillington
Reid Lake
Moose Lake
MATHESON
Destor - Porcupine Fault Zone
Perry Lake
McDiarmid Lake
Holtyre
Ramore
Ghost Lake
Webster Lake
80°49'
79°30'
48°22'
0
10
20 km
1
2
3
4
5
6
11
101
Granitic-syenitic plutonic rocks
Metasediments
Mafic metavolcanics
Layered ultramafic-mafic complexes
Fault
1 Hedman Mine, serpentine filler
2 Egan Township, feldspar flux
3 Munro Mine, talc, magnesite
4 Garrison stock, facing stone
5 Munro Township, Potterdoal (N) Potter (S) Mine areas, crushed stone
6 Harker Township, crushed stone

***Figure 1.** General geology of the BRIM area and localities of industrial mineral prospects. (Project S62.)*

Approximately 7 km^2 of the northwestern part of the intrusion are well exposed and were examined during the 1985 field season. Most of the exposures are massive hornblende syenite with minor hornblende granite or quartz monzonite. These rocks are intruded by a series of north-trending diabase dikes. The syenite is estimated to contain at least 60% and up to 80% pink alkali feldspar, with 5% to 40% hornblende and locally up to 5% sphene. It is generally coarse grained to pegmatitic with finer grained varieties in complex, crosscutting dikes. Quartz veins are rare. In hand specimen, the rock is pink with a high content of fine to coarse grained euhedral potassium feldspar. Finer grained euhedral hornblende and fine euhedral sphene are inhomogeneously disseminated within the rock. A massive, medium grained hornblende granite or quartz monzonite phase occurs in the south central part of the exposure examined. This phase contains up to 25% quartz and 10% hornblende.

TALC AND MAGNESITE

The only reported occurrence of talc and magnesite in the BRIM area is at the Johns-Manville Munro Asbestos Mine, a past producer of chrysotile asbestos (Kretschmar and Kretschmar 1982). The deposit occurs in south Munro Township in an east-southeast trending ultramafic complex located north of the Destor-Porcupine Fault within the Stoughton-Roquemaure Group.

Hendry (1951) described an "envelope" of talc-magnesite rock around the eastern end of the Munro Mine open pit. On surface, the zone is very narrow (1 m) or absent along the north and south margins; however, the south zone thickens to over 30 m at a depth of about 225 m. Drill results indicate that the zone may occur in a keel-like form at the eastern end of the deposit (Vos 1971). A hand specimen of the material collected from the pit area is massive, fine to medium grained, and contains an estimated 40% talc and 60% magnesite. The total tonnage and extent of the zone are unknown and extraction would require underground mining methods.

BUILDING STONE

The Garrison stock in central Garrison Township is the only reasonably accessible felsic intrusive rock which has significant potential for facing and monument stone. The intrusion is roughly triangular and covers an area of approximately 10 km^2. It is a homogeneous, light pink, massive to weakly porphyritic, fine to medium grained hornblende granite. The granite contains no deleterious minerals such as sulphide mineralization, highly altered feldspar, or soft ferromagnesian minerals. A major north-trending fault passes through the centre of the intrusion and forms a prominent topographic depression. Outcrops observed west of the fault and in the southeastern part of the intrusion all contain planar quartz and quartz plus potassium feldspar veinlets and altered, fractured zones. Only the northeastern part of the granite lacks the vein, alteration, and fracture density suitable for facing and monumental stone. The best exposures of the intrusion occur within an area of about 0.5 km^2 of the northwestern corner.

A number of localities could provide crushed stone for aggregate or road fill. The best prospects are areas which have steep, well exposed outcrop faces to facilitate quarrying and good road access. Two areas in north central Munro Township, near the old Potter and Potterdoal Mine sites, are suitable. The Centre Hill complex south of the Potter Mine and the extensive Munro-Warden complex near the Potterdoal Mine are comprised of interlayered sills and flows of gabbro, peridotite, and pyroxenite. Both areas are easily accessible by a well maintained gravel road running north from Highway 101. Similarly, in the northern part of Harker Township, the Ghost Range is accessible from Highway 101 by well maintained logging roads. The steep outcrops of the Ghost Range are predominantly massive gabbros.

ACKNOWLEDGMENTS

Special thanks to Mr. J.J. Mangan, President, Hedman Resources Limited, for allowing access to the Hedman Mine and claims and to Dave Kingston for his able field assistance throughout the season.

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S63. Reconnaissance Till Sampling Program, Matheson-Lake Abitibi Area, Cochrane District

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This project is part of Operation Black River-Matheson (BRIM) which was funded equally by the Ontario Ministry of Northern Affairs and Mines and the Ontario Ministry of Natural Resources.

INTRODUCTION

The object of this BRIM project is to stimulate exploration and development in the Black River-Matheson area. The release of geochemical data and stratigraphic information are examples of direct stimulation. Indirect stimulation is provided through research on parameters and factors which influence or alter the interpretation of existing data.

QUATERNARY HISTORY

The study area was deglaciated approximately 10 000 years before present. The most recent glacial advance was towards 170° azimuth and deposited the Matheson till (informal name). During the later stages of ice cover, the large and numerous esker systems which trend parallel to the ice flow direction were established. As the ice front wasted to the north, it was fronted by Lakes Barlow and Ojibway. The existence of these bodies of water resulted in the deposition of thick and extensive glaciolacustrine clay deposits which mask most of the bedrock and flank or lap onto the eskers.

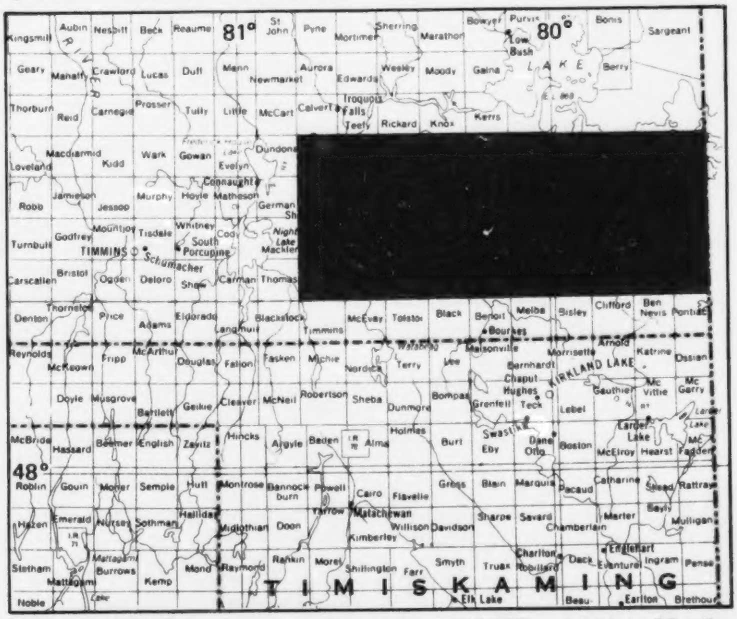
Overburden drilling in the Matheson area has indicated the presence of an older glacial package under the Matheson till. These older deposits are scattered and usually occur in bedrock depressions on the southern, or lee side of bedrock highs. This lower package generally consists of varved clay over till.

TILL SAMPLING

During the fall of 1984 and during the 1985 summer field season, the Geochemistry/Geophysics Section and the Engineering and Terrain Geology Section of the Ontario Geological Survey undertook an applied program of geochemical studies and Quaternary geology mapping in the Matheson area (Location Map). This program provided an exploration oriented regional glacial stratigraphy and a till geochemistry database. Data was collected either by trenching with a backhoe or by sonic drilling. In each case, a complete drift sequence from the ground surface to bedrock was available for description and sampling.

BACKHOE PROGRAM

Backhoe till sampling in areas with shallow drift was carried out in the central and eastern parts of the BRIM area. The corner townships of this area are (clockwise from the southwest): Cook, Warden, Stoughton-Lake Abitibi, and Dokis. Highway 101 serves as the main access route and bisects the area


81°
80°
Kingsmill
Aubin
Nesbitt
Beck
Reaume
St John
Pyne
Mortimer
Sherring
Marathon
Bowyer
Purvis
Bonis
Sargeant
Low Bush
Geary
Mahaffy
Crawford
Lucas
Duff
Mann
Newmarket
Aurora
Edwards
Wesley
Moody
Gaina
LAKE
Berry
Thorburn
Reid
Carnegie
Prosser
Tully
Little
McCart
Calvert
Iroquois Falls
Teefy
Rickard
Knox
Kerrs
Macdiarmid
Kidd
Wark
Gowan
Dundonald
Loveland
Evelyn
Connaught
Robb
Jamieson
Jessop
Murphy
Hoyle
Matheson
German
Turnbull
Godfrey
Mountjoy
Tisdale
Whitney
South Porcupine
Cody
Night Lake
Mackler
TIMMINS
Schumacher
Carscallen
Bristol
Ogden
Deloro
Shaw
Carman
Thomas
Denton
Thorneloe
Price
Adams
Eldorado
Langmuir
Blackstock
Timmins
McEvay
Tolstoi
Black
Benoit
Melba
Bisley
Clifford
Ben Nevis
Pontiac
Bourkes
Reynolds
McKeown
Fripp
McArthur
Douglas
Fallon
Fasken
Michie
Nordica
Terry
Lee
Maisonville
Morrisette
Arnold
Katrine
Ossian
Bernhardt
KIRKLAND LAKE
Chaput Hughes
Gauthier
Mc Vittie
Mc Garry
Doyle
Musgrove
Bartlett
Geikie
Cleaver
McNeil
Robertson
Sheba
Bompas
Dunmore
Grenfell
Teck
Lebel
Larder Lake
McBride
Hassard
Beemer
English
Zavitz
Hincks
Argyle
Baden
Alma
Holmes
Burt
Swastika
Eby
Dane
Otto
Boston
McElroy
Hearst
McFadden
48°
Roblin
Gouin
Mohler
Semple
Hutt
Montrose
Bannockburn
Powell
Cairo
Flavelle
Gross
Blain
Marquis
Pacaud
Catharine
Skead
Rattray
Hazen
Emerald
Nursey
Sothman
Halliday
Midlothian
Doon
Tarrow
Matachewan
Willison
Davidson
Sharpe
Savard
Chamberlain
Marter
Bayly
Mulligan
Kimberley
Strathearn
Mattagami
Burrows
Kemp
Mond
Raymond
Rankin
Morel
Shillington
Farr
Smyth
Truax
Charlton
Robillard
Dack
Evanturel
Englehart
Ingram
Pense
Noble
TIMISKAMING
Elk Lake
Beauchamp
Earlton
Brethour

LOCATION MAP Scale : 1 : 1 548 000 or 1 inch to 25 miles

TABLE 1. DISTRIBUTION OF BACKHOE TILL SAMPLES (PROJECT S63)

Township	No. of Samples
Cook	7
Barnet	*
Thackeray	11
Elliott	2
Tannahill	*
Dokis	*
Marriott	11
Halloway	6
Harker	24
Garrison	20
Michaud	2
Guibord	10
Munro	18
McCool	4
Indian Reserve #70	3
Rand	8
Lamplugh	18
Frecheville	*
Stoughton	2
Milligan	1
Warden	1
	148

*No access

in an east-west direction. Additional access was along mine, lumber and exploration roads and trails.

GEOLOGICAL SETTING

In the study area, till usually occurs at the base of the overburden stratigraphic sequence. The till may be overlain by: (1) glaciofluvial sand, and/or (2) glaciolacustrine clay, silt, and sand, although, on occasion the till may be found at the surface.

Where the glaciofluvial and glaciolacustrine deposits are thin or absent, the till may be sampled by backhoe trenching. Backhoe sampling of till can be carried out around bedrock knobs that protrude through the clay or sand plains, in areas of abundant outcrop and where till is exposed at surface.

PROJECT RATIONALE

The advantages of a backhoe sampling program are: (1) wheeled backhoes can be quickly moved over large distances, (2) trenches up to 3 m in depth can be dug rapidly with minimal disturbance to the surrounding area, (3) large samples of fresh material are obtained, (4) a stratigraphic section is exposed in the trench wall, and (5) compared with hand digging or drilling, backhoeing is a cost effective way of obtaining shallow, bulk till samples. The limitations of a wheeled backhoe sampling program are: (1) the machine can only be used along roads or on cleared, relatively smooth, ground, and (2) it is practical to trench only at sites where till is exposed at surface or around bedrock outcrops where the probability of finding till is high.

SITE SELECTION

A list of potential sample sites was compiled from published Quaternary geology and bedrock geology maps. Positions of outcrops located near roads or in cleared areas were obtained from the bedrock geology maps. Quaternary geology maps (Baker *et al.* 1980, 1982; Vagners 1985; Vagners and Courtney 1985) provided locations of till exposures and areas of bedrock-drift complex where till was likely to occur near the surface. Air photographs were examined to identify new or impassable roads. Potential sample sites were field checked to ensure ready accessibility. New roads were travelled so that any additional bedrock outcrops or till exposures not previously known would be included in the trenching program.

EQUIPMENT

Wheeled, rubber-tired backhoe loaders with an extendahoe option were used for a total of 352 hours. The backhoe models used were Case® 580B, Case® 580C, and John Deere® 410.

In the program 177 sites were trenched. On the average, two hours were required to dig, sample, and backfill a trench and drive the backhoe to the next site. At each site, if till was not found in the first trench, up to two additional trenches were dug.

SAMPLING RESULTS

Pit depth varied from site to site and was controlled primarily by the topography of the bedrock surface. To obtain fresh till, samples were taken below a depth of 1.0 m whenever possible. Sampling depths ranged from 0.3 to 3.0 m, with the average being approximately 1.7 m. When till was found in a trench, one 8 to 10 kg and two 250 g samples were taken, the till properties were recorded in detail and the overburden stratigraphy exposed in the pit was described. The preferred sampling position in a trench was within 0.5 m of the till-bedrock interface.

The till seen in the trenches generally had a massive, compact, silty sand matrix with a clast (+10 mesh) content of 10% to 25%. Typically, clast angularity ranged from extremely angular to subrounded. In general, metavolcanic and metasedimentary clasts were much more angular than intrusive clasts. At most sites, the till was interpreted to be subglacially deposited as indicated by: (1) the abundance of locally derived clasts; (2) the overconsolidated nature of the material; and (3) clast shape.

A total of 148 till samples were collected from the 177 sites. The number of till samples obtained by backhoe trenching per township is listed in Table 1.

DRILL PROGRAM

The drill program carried out in the fall of 1984 was undertaken in a four by four township block at the western end of the BRIM project area (Location Map). The townships within the block lie mainly within the boundaries of the Corporation of the Township of Black River-Matheson and the Corporation of the Town of Iroquois Falls. The majority of the land in this area has been cleared for agriculture and has a well developed road network. With the exception of the bedrock highlands in the southwestern corner of the area, the clay cover is extensive.

The 1985 drilling took place along road access in the 20 townships at the eastern end of the BRIM area. In addition, fill-in drilling was completed in the northwestern and southwestern corners of the 1984 area.

DRILL HOLE SITE SELECTION

Drill hole site selection was constrained by the following factors:

1. the provision of an even distribution of data points (trenches and drill holes) over the study area;
2. the location of sites down-ice of the Destor-Porcupine and Pipestone fault zones;
3. the avoidance of esker core sediments;
4. the necessity of using roads and bridges capable of supporting a 14 ton drill rig.

Within these constraints the majority of drill sites were positioned over geophysically defined buried bedrock valleys (Pitcher *et al.* 1984), the axes of which trend perpendicular to the most recent (170°) direction of glaciation. These valleys were drilled with the belief that the most complete Quaternary stratigraphy in the area would be encountered. Other sites were selected on the basis of bedrock geology.

EQUIPMENT

The equipment chosen for the BRIM deep overburden sampling was the rotasonic or, more commonly, sonic drill operated by Midwest Drilling. This equipment provides core samples which allow detailed stratigraphy to be observed, logged, and sampled. In addition, the core produced is suited for core library storage for future reference and study.

The rotasonic drill uses vibration and rotation to advance the bit. Minimum compaction or disturbance of the core takes place and no drilling fluid is required. Representative cores of all material from soft clay to boulders and bedrock can be obtained.

In the 1984 drilling program, a skid mounted drill was employed. This arrangement had the advantages of being:

1. moved rapidly by truck between sites;
2. easily positioned in all ground conditions;
3. able to be pulled across the ditches which flank many of the roads in the area;
4. lighter and lower than a Nodwell® mounted unit.

The drill was transported between holes by a goose neck type low bed float. A John Deere® Model 640 log skidder was used to winch the drill skid on and off the low bed and to position the drill at the site. The drill contractor used a three-ton truck to store spare rods and casing and to deliver water to the drill site. Water was used to flush casing down outside the drill rods and to drill bedrock.

In the 1985 drill program, a truck mounted drill system was used. The change to a truck mount was possible through:

1. the roads in the 1985 area having no or very shallow ditches;
2. a drier summer combined with an early drilling period (August-September) which had left the ground surface much firmer than in 1984.

As a result of this change, move times were reduced as the drill did not have to be loaded or unloaded and the overall cost was lower because a low bed float was not required.

The drill was secured to a Sicard® six-wheel drive drill truck. Drill rods and casing were carried on a three-ton truck which was backed up to the drill at the site. A 3/4-ton pickup was used to haul water.

In both 1984 and 1985, field operations were supported by a 10 by 20 foot trailer. The trailer was used to log core in inclement weather and during the winter part of the 1984 season. It also served to store and transport core boxes and drilling equipment. The trailer was moved between sites by the three-ton truck.

DRILLING FIELD OPERATIONS

In both years of the drilling, three technical staff were deployed on the drill whose respective duties were to: (1) monitor bit penetration; (2) log core; and (3) take samples. The sonic drill crew also consisted of three persons, the driller, the driller's helper, and a waterhauler.

The 1984 drill program resulted in 42 holes being drilled with an average overburden thickness of 35.4 m. Two holes were abandoned before reaching bedrock. Drilling took place in one 12 hour shift per day over a 37 day period. Moves between holes averaged 8 km and required 1.8 hours. Down time was held to an enviable 4.6%. In total, 1564 m was drilled with an average production rate of 3.75 m per hour.

Sixty holes were completed in the 1985 program. One of these was abandoned before bedrock was reached because of excessive depth. Overburden averaged 42.1 m per hole. Moves between sites ranged from 2 to 30 km and took from 15 minutes to 2.5 hours to complete. In total, 2595 m were drilled over a 42 day period.

LOGGING AND SAMPLING

Core was extruded from the core barrel into plastic sleeves. It was then transferred to the logging area or trailer where the sleeves were slit open and the material examined. Footages were assigned based on observations of the person logging penetration and the type of material present.

Following the recording of a detailed description of the material, till, sand and gravel were placed in wooden core boxes and sampled. Clay, with the exception of four holes kept for scientific study, was discarded.

Complete core recovery was usually achieved in clay and till sequences with structures and thinly bedded units easily recognized. Recovery in sands and gravels averaged 80% with all fine sedimentary structures destroyed during drilling and extrusion of the core from the rods. Bedrock recovery varied with lithology and ranged from 50% to 90%. Of the total core logged from the 1984 program, 47% was clay,

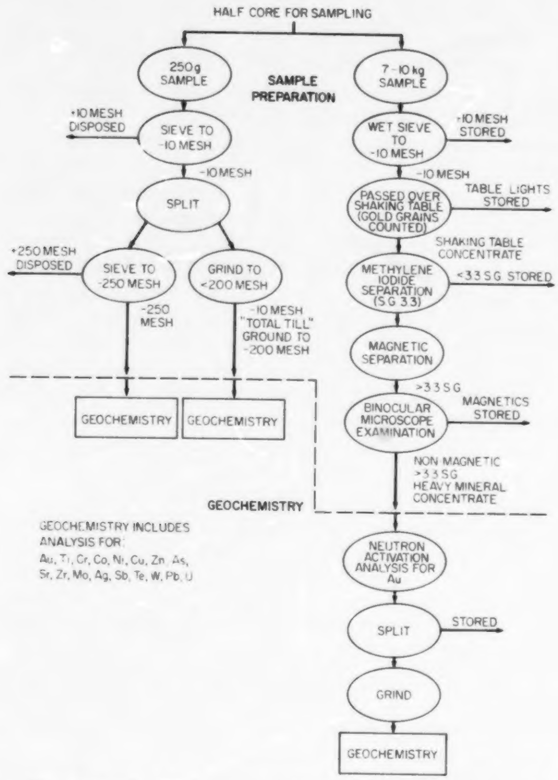

HALF CORE FOR SAMPLING
250 g SAMPLE
SAMPLE PREPARATION
7-10 kg SAMPLE
+10 MESH DISPOSED
SIEVE TO -10 MESH
-10 MESH
SPLIT
+250 MESH DISPOSED
SIEVE TO -250 MESH
GRIND TO <200 MESH
-250 MESH
-10 MESH "TOTAL TILL" GROUND TO -200 MESH
GEOCHEMISTRY
GEOCHEMISTRY
WET SIEVE TO -10 MESH
-10 MESH STORED
-10 MESH
PASSED OVER SHAKING TABLE (GOLD GRAINS COUNTED)
TABLE LIGHTS STORED
SHAKING TABLE CONCENTRATE
METHYLENE IODIDE SEPARATION (SG 3.3)
<3.3 S.G. STORED
MAGNETIC SEPARATION
>3.3 S.G.
BINOCULAR MICROSCOPE EXAMINATION
MAGNETICS STORED
NON MAGNETIC >3.3 S.G. HEAVY MINERAL CONCENTRATE
GEOCHEMISTRY
GEOCHEMISTRY INCLUDES ANALYSIS FOR: Au, Ti, Cr, Co, Ni, Cu, Zn, As, Sr, Zr, Mo, Ag, Sb, Te, W, Pb, U
NEUTRON ACTIVATION ANALYSIS FOR Au
SPLIT
STORED
GRIND
GEOCHEMISTRY

***Figure 1.** Sample preparation flow chart for backhoe and drill samples. (Project S63.)*

23% was sand or gravel, 21% was till and 5% was bedrock or large boulders.

Sampling was done on a stratigraphic basis rather than at a fixed interval. Where possible, till was sampled over a 1.5 m length, whereas sand and/or gravel was sampled over 3 m, 6 m or, exceptionally, 10 m intervals. A sample weighed approximately 7 to 10 kg and would consume approximately half of a 1.5 m length of core. Large clasts were picked from the matrix of the sample and returned to the core box or held for identification at a later date.

Two smaller sample splits weighing approximately 250 gm were also collected. One was for size analysis and carbonate determinations and the other for geochemical analysis on the fine fraction of the samples.

Once sampling was complete, lids were fastened to the boxes and they were transported to a temporary storage facility near Matheson. It is expected that the core will be placed on display at the Kirkland Lake Core Storage Library in late 1985.

SAMPLING PROCESSING

Backhoe and drill samples collected as part of this program were processed in the manner outlined in Figure 1. During the processing of the 7 to 10 kg bulk sample for the separation of the heavy minerals, gold grains were counted and the heavy mineral suite visually examined. Neutron activation analysis for gold was done on the entire heavy mineral concentrate to provide the most reliable geochemical analysis possible. Geochemistry for the remaining elements listed on Figure 1 was completed using a minimum of 10 gm of the heavy minerals.

Two fractions of the till matrix were also analyzed: the -250 mesh material, and the -10 mesh material (ground to -200 mesh prior to analysis). Work on these fractions is being undertaken in order to determine if mineralization in the BRIM area is reflected in the fine sediment portion of the till.

In an attempt to determine the extent, nature, and variability of the bedrock in the glacial sediments, whole rock analyses are also being completed on the ground, -10 mesh material. The results of these analyses should prove useful in determining the provenance of the various glacial deposits and the character or type of the up-ice bedrock.

PRELIMINARY RESULTS OF THE TILL PROGRAM

Full results of the 1984 drilling and backhoe till sampling are expected to be released shortly. Results of the 1985 program should be available by mid 1986.

Logs of the drill holes confirm the presence of at least two till sheets in the Matheson area. The upper till (youngest) which advanced towards 170° azimuth is well documented. Much less was known of the lower till, encountered in approximately 30% of the 1984 holes. Drilling and field work associated with the program have now served to establish a 240° azimuth as the direction of flow for the ice depositing this till. In several instances, the tills are separated by a thick sequence of glaciolacustrine varved clay. In other cases, thin deposits of clay or sand lie between the tills. There also appear to be areas where the two tills are in contact but separating them, or defining the contact between them is often difficult. Mineralogy, geochemistry, and textural analysis have been found to be useful in helping to distinguish the contact in some situations.

Preliminary information on the number and distribution of visible gold grains in the sonic drill core samples was available in late 1984 (Baker *et al.* 1984). The presence of a significant number of gold grains in the heavy mineral fraction is of interest in exploration because they are a direct indication of mineralization. Where several adjacent vertical till samples yield gold grain counts exceeding the regional background value, the source is likely nearby in the "up-ice" direction. High counts of visible gold grains are particularly significant when they occur in till samples taken directly above bedrock as this indicates an immediate proximity to the mineralization. Of the till samples taken from the 1984 sonic drill core in the Matheson area, approximately 55% had no visible gold grains and 30% contained background values of 1 to 3 grains per sample. The remaining 15% of the till samples had >3 gold grains per sample. Within this anomalous group, there are samples from two holes with a significant number of gold grains in the till samples taken directly over bedrock, and samples from two holes where several vertically adjacent samples yielded significant gold grain counts. This preliminary information will be supplemented by mineralogical and detailed geochemical data for both sonic and backhoe samples when it becomes available.

Results of the examination of the bedrock cores obtained from the base of the drill holes was reported on by Jensen *et al.* (1985). Whole rock analyses and thin section descriptions of the rocks are to be published in the near future.

ACKNOWLEDGMENTS

Field work described herein was completed by the authors with the competent assistance of D.R. Wadge, D.L. Archibald and J.T. Aultman. The Ontario Geological Survey wishes to thank individuals and companies who were party to discussions, who provided access to properties, and who allowed sampling by drilling or trenching. Particular thanks are extended to Mr. A.H. Baragar, Corporation of the Townships of Black River-Matheson; Mr. Ross Peever, Corporation of the Town of Iroquois Falls, and the staff of the Ontario Ministry of Transportation and Communications, Iroquois Falls and New Liskeard offices.

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S64. A Correlation of Airborne and Ground Electromagnetics with Sonic Drilling Results in the Black River-Matheson (BRIM) Area, District of Cochrane

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This project is part of Operation Black River-Matheson (BRIM) which was funded equally by the Ontario Ministry of Northern Affairs and Mines and the Ontario Ministry of Natural Resources.

INTRODUCTION

The Ontario Geological Survey initiated an overburden sonic drilling program in the vicinity of Matheson, Ontario and completed 42 holes in the 16 western townships of the BRIM area by the fall of 1984. The sonic drilling program was designed to sample areas that are predicted to contain thick Quaternary sections associated with bedrock valleys, and provide explorationists with information regarding the mineral potential of the area. In order to assist in the selection of such areas of thick overburden cover, a technique was developed by Pitcher *et al.* (1984) to map the nature and aerial extent of conducting overburden in the area using the results of the Questor INPUT® airborne time-domain electromagnetic system. Barlow and Krentz (1984) employed both, the Geonics EM-37 to locate buried valleys where a second layer of lesser conductivity and thickness was present, and the combined EM-31/EM-34 physical property measurements to derive an average conductivity of clay between 32.6 and 37.3 millisiemens/metre.

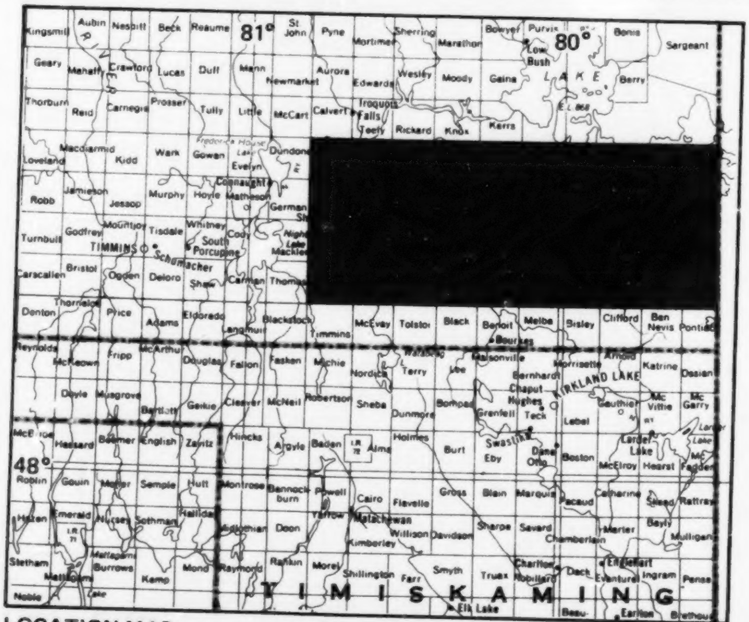
In order to evaluate the effectiveness of electromagnetic measurements in deriving electrical conductivities and thicknesses of multi-layered Quaternary stratigraphy, the drill hole logs can be used in conjunction with observations from various types of electromagnetic systems. In the present paper the INPUT® system and the combined EM-31/EM-34 instrumentation results, in the vicinity of the drill hole sites, are interpreted using horizontally stratified earth models.

AIRBORNE ELECTROMAGNETIC RESULTS

MODEL

The system configuration for INPUT® is shown in Figure 1, along with the electrical subsurface model that is commonly used to represent conducting overburden situated in a very resistive Precambrian bedrock. Only the conductance, which is the product of conductivity and thickness, of the conducting overburden can be determined, and not the conductivity and thickness separately. This model is often referred to as the thin sheet model. The interpretation nomogram for this model is presented in Pitcher *et al.* (1984).

Under conditions of extremely high conductance (i.e. greater than about 4 siemens), the conductivity-thickness product can be determined independently at the six different measuring times of the INPUT® system. In the BRIM area, however, the overburden


81°
80°
48°
TIMMINS
Schumacher
Matheson
Iroquois Falls
KIRKLAND LAKE
L A K E
T I M I S K A M I N G
Larder Lake
Kingsmill
Aubin
Nesbitt
Beck
Reaume
St. John
Pyne
Sherring
Bowyer
Purvis
Benoit
Sargeant
Geary
Mahaffy
Crawford
Lucas
Duff
Mann
Aurora
Newmarket
Mortimer
Edwards
Wesley
Moody
Gaina
Berry
Thorburn
Reid
Carnegie
Prosser
Tully
Little
McCart
Calvert
Teefy
Rickard
Knox
Kerrs
Macdiarmid
Loveland
Kidd
Wark
Gowan
Lake Evelyn
Dundonald
Jamieson
Robb
Jessop
Murphy
Hoyle
Connaught
German
Turnbull
Godfrey
Mountjoy
Tisdale
Whitney
South Porcupine
Cody
Carscallen
Bristol
Ogden
Deloro
Shaw
Carman
Thomas
Denton
Thornloe
Price
Adams
Eldorado
Langmuir
Blackstock
Timmins
McEvay
Tolstoi
Black
Benoit
Melba
Bisley
Clifford
Ben Nevis
Pontiac
Reynolds
McKeown
Fripp
McArthur
Douglas
Fallon
Fasken
Michie
Nordica
Terry
Bourkes
Larder
Lebel
Katrine
Ossian
Doyle
Musgrove
Bartlett
Geikie
Cleaver
McNeil
Robertson
Sheba
Dunmore
Bompas
Grenfell
Teck
Gauthier
McVittie
McGarry
McBride
Hassard
Beemer
English
Zavitz
Hincks
Argyle
Baden
Alma
Holmes
Burt
Swastika
Eby
Otto
Boston
McElroy
Hearst
McFadden
Roblin
Gouin
Mahler
Semple
Hutt
Montrose
Bannockburn
Powell
Cairo
Flavelle
Gross
Blain
Marquis
Pacaud
Catharine
Skead
Rattray
Halliday
Emerald
Nursey
Sothman
Doon
Yarrow
Matachewan
Kimberley
Willison
Davidson
Sharpe
Savard
Chamberlain
Marter
Bayly
Mulligan
Stetham
Mattagami
Burrows
Kemp
Mond
Raymond
Rankin
Morel
Shillington
Smyth
Truax
Charlton
Robillard
Dack
Englehart
Evanturel
Ingram
Pense
Noble
Farr
Elk Lake
Beauchamp
Earlton
Bethoud

LOCATION MAP

Scale : 1 : 1 548 000 or 1 inch to 25 miles

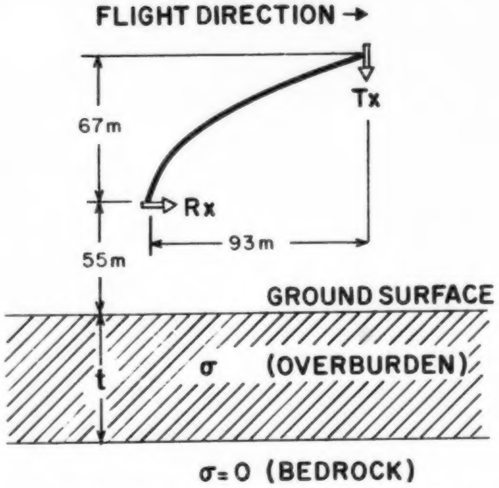


Figure 1. *System configuration and simplified subsurface model to represent conducting overburden. (Project S64.)*

conductance rarely exceeds 1.5 siemens, so that determinations can be obtained on, at most, the first two or three channels. A useful parameter for deriving overburden conductance under these conditions has been found to be the difference between channels 1 and 2. The difference, when applied to overburden mapping, has the inherent advantage of reducing linear baseline drifts of the same polarity, first order removal of longer time constant responses due to bedrock conductors, and reducing cultural noise due to powerlines, fences, etc.

DRILL LOGS

Two preliminary maps have been published outlining the drill hole locations on a regional scale of 1:100 000. The first map (Baker *et al.* 1984) summarizes the visible gold grains in the till and glaciofluvial (sand and gravel) samples, as well as summarizing the drill hole logs. The second map (Jensen *et al.* 1985) presents the preliminary results of the bedrock samples.

TABULATION OF RESULTS

In the majority of cases, the sonic drill intersected a sequence consisting of a single layer of glaciolacustrine clay underlain by one or more layers of till and glaciofluvial (sand and gravel) material. At less than 20% of the drill hole sites there are multiple layers consisting of a first clay layer, followed by a sequence of one or more till and glaciofluvial layers, underlain by further layers of clay, sand, gravel, and even till. Finally, at two of the sites only sand, till, and boulders were intersected.

Since the airborne results were interpreted using a very simple thin sheet model, where only the conductance of the entire overburden sequence is derived, it was decided to evaluate the effectiveness of the method in mapping the most conductive overburden unit, namely clay. The results of this evaluation are summarized in Table 1.

The conductance was determined from the airborne system response in the vicinity of each drill hole site. By least squares, fitting interpreted conductance versus total clay layer thickness to a straight line of the form y = mx, an average value for the apparent conductivity of the clay can be derived, which is simply the slope (m) of the line (Figure 2). In this case, the average apparent conductivity was derived to be 33.8 millisiemens/metre which is consistent with the expected value for this type of massive varved clay. The clay thickness was derived from the electromagnetic results by dividing the conductance by the average conductivity of 33.8 millisiemens/metre. Also, the percent error, between the interpreted clay layer thickness and the total clay layer thickness from drilling, is tabulated.

The airborne electromagnetic method was successful in determining the cumulative thickness to an accuracy of 35% or better, at about 60% of the drill hole sites. At two of the hole sites yielding significantly inconsistent results, holes 2 and 13, electromagnetics greatly overestimated the thickness of clay to be 13 and 12 m, where the actual thickness is 7 and 3 m, respectively. However, the level of detectability of clay layers with this system is about 10 m, so that these predictions were based upon responses near the threshold of sensitivity. Large errors also occur near sites 11, 24, and 33, and are most likely due to the presence of bedrock conductor responses distorting the predicted overburden response by greatly enhancing the interpreted response.

GROUND ELECTROMAGNETIC RESULTS

INSTRUMENTATION

In order to better define the electrical characteristics of the overburden in the vicinity of each drillhole site, a series of measurements was carried out at surface, employing both the Geonics EM31-D and EM34-3 XL electromagnetic units. The EM31-D is designed to sense changes in ground conductivity to depths of about 6 m, while the EM34-3 XL has a depth of investigation on the order of 60 m.

The EM31-D is a rigid boom system with a 3.67 m coil separation. The instrument is designed to measure in the vertical dipole mode, where the maximum depth of penetration is achieved, as well as to measure in the horizontal dipole mode to define the electrical characteristics of the upper few metres. In order to resolve two near-surface conducting layers, measurements were also taken both on the ground and at an elevation of 1 m above the ground. Hence, four different measurements were taken using the unit.

The EM34-3 XL is also designed to measure in the vertical and horizontal dipole modes to detect vertical variations of conductivity with depth. Furthermore, measurements can be taken at 3 coil separations, 10, 20, and 40 m, which can be used in conjunction with the variable mode results to define changes in conductivity with depth. This unit, therefore, allowed the measurement of an additional six parameters.

TABLE 1. SUMMARY OF 1984 SONIC DRILL HOLE LOGS AND AIRBORNE ELECTROMAGNETIC DATA INTERPRETATION. THE CLAY LAYER THICKNESS INTERPRETED FROM THE EM RESULTS WAS BASED UPON A CONDUCTIVITY OF 33.8 MILLISIEMENS/METRE. (PROJECT S64)

DRILL LOGS					EM INTERPRETATION		
Hole No.	Depth to Bedrock (metres)	Total Clay (metres)	Number of Clay Layers	Total Till (metres)	Conductance (siemens)	Interpreted Clay (metre)	Error (%)
1	31.6	14.0	1	5.6	.83	24.6	76[1]
2	11.9	7.3	2	1.5	0.43	12.7	74[2]
3	36.0	2.4	1	0.0	<0.34	<10.1	-
4	32.3	17.7	1	0.3	0.51	15.1	-15
5	29.9	15.2	1	0.0	0.66	19.5	28
6	32.6	19.8	1	12.8	0.77	22.8	15
7	35.4	16.5	1	9.9	0.89	26.3	59[1]
8	21.8	9.9	1	2.0	0.74	21.9	121[1]
9	46.3	15.2	1	0.3	0.96	28.4	87[1]
10	47.6	11.6	1	0.6	0.76	22.5	94[1]
11	14.9	12.2	1	2.7	0.58	17.2	41[3]
12	24.4	6.7	1	15.9	<0.34	<10.1	-
13	34.1	3.4	1	30.8	0.39	11.5	239[2]
14	35.1	29.0	2	2.9	0.64	18.9	-35
15	65.2	0.0	0	8.2	<0.34	<10.1	-
16	31.7	23.8	1	0.0	0.64	18.9	-21
17	37.2	13.4	1	2.3	0.55	16.3	22
18	27.4	20.4	1	0.0	0.79	23.4	15
19	8.5	0.0	0	2.7	<0.34	<10.1	-
20	35.4	26.5	1	0.5	0.92	27.2	3
21	76.2	53.3	1	0.2	1.19	35.2	-34
22	29.6	14.3	1	1.5	0.76	22.5	57[1]
23	25.5	17.5	1	7.9	0.89	26.3	51[1]
24	28.3	15.4	1	13.0	0.88	26.0	69[3]
25	35.4	11.0	1	18.6	0.61	18.1	64[1]
26	33.7	7.6	1	18.4	0.64	18.9	149[1]
27	49.1	32.8	3	10.4	0.91	26.9	-18
28	60.5	27.7	2	31.4	0.89	26.3	-5
29	25.0	11.9	1	13.1	0.66	19.5	64.1[1]
30	18.0	14.2	1	3.8	0.61	18.1	27
31	57.9	31.3	2	3.1	0.84	24.9	-21
32	35.1	20.4	1	3.2	0.63	18.6	-9
33	29.6	7.6	1	22.0	0.64	18.9	149[3]
34	28.4	21.0	1	6.7	0.73	21.5	3
35	51.8	13.1	2	28.0	0.73	21.6	65[1]
36	36.6	19.4	1	17.2	0.73	21.6	11
37	50.0	25.0	1	21.0	0.68	20.1	-20
38	35.4	32.3	1	3.1	1.15	34.0	5
39	43.9	36.3	1	1.1	1.06	31.4	-14
40	20.4	17.4	2	3.0	0.56	16.6	-5
41	53.0	40.5	1	0.0	1.26	37.3	-8
42	14.3	14.3	1	0.0	0.76	22.5	57[1]

NOTE:

[1] Significant overestimate of clay thickness.

[2] Low amplitude EM response.

[3] Enhanced EM response due to a bedrock conducter.

MODEL

Both ground electromagnetic units used for these experiments are designed to operate at so-called low induction numbers (McNeill 1980) where, for a uniform earth model (i.e. conductivity is constant with depth), the apparent conductivity measured by the unit is given by the following equation:

$$\sigma_a = \frac{4}{\omega\mu_o s^2}\left(\frac{H_s}{H_p}\right)$$

where H_s = secondary magnetic field at the receiver coil
H_p = primary magnetic field at the receiver coil
$\omega = 2\pi f$
f = frequency (Hz)
μ_o = permeability of free space
σ = ground conductivity (mho/m)
s = intercoil spacing (m)

In order to derive the maximum amount of information regarding the electrical section of the ground from the six EM34 and 4 EM31 observations, a more complex model of the overburden was used than the simple thin sheet. Figure 4 shows the 3-layer model employed to interpret the data, and takes into account the set of EM31 measurements when the unit is raised 1 m above the ground. The upper two layers represent conducting overburden which in the Matheson area often corresponds to a near-surface conducting clay layer of the order of 30 millisiemens/metre, underlain by a less conducting layer consisting of till, sand, and/or gravel, which is at least an order of magnitude less conducting than the upper clay layer. The third layer is used to represent highly resistive bedrock which is generally much less than 1 millisiemen/metre.

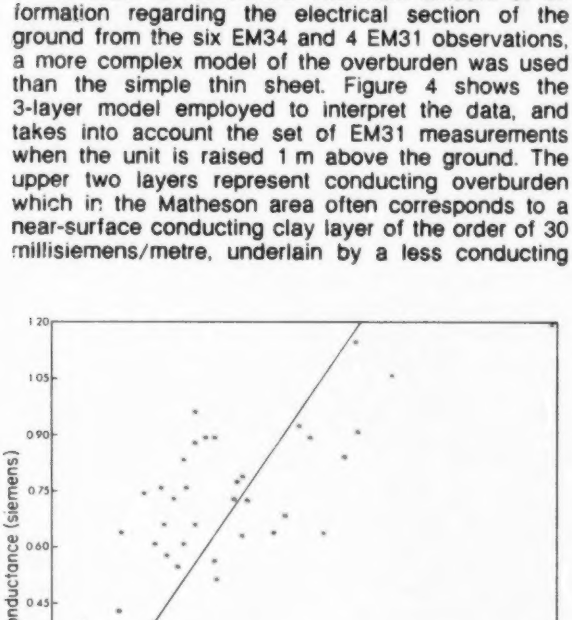


Figure 2. Conductance derived from airborne electromagnetics versus total clay thickness (drilling) fitted to a straight line of the form y=mx. (Project S64.)

From McNeill (1980) it is easy to derive the following expressions at low induction numbers which correspond to the ten apparent conductivity observations measured by the electromagnetic units:

6 EM34 Observations

$$\sigma_{aH}(S) = \sigma_1[1 - R_H(Z_1/S)] + \sigma_2[R_H(Z_1/S) - R_H(Z_2/S)] + \sigma_3 R_H(Z_2/S)$$

$$\sigma_{aV}(S) = \sigma_1[1 - R_V(Z_1/S)] + \sigma_2[R_V(Z_1/S) - R_V(Z_2/S)] + \sigma_3 R_V(Z_2/S)$$

where $\sigma_{aH}(S)$ = Apparent conductivity for the horizontal dipole measurement
$\sigma_{aV}(S)$ = Apparent conductivity for the vertical dipole measurement
S = 10, 20 and 40 metres
$R_H(Z/S) = \sqrt{4(Z/S)^2 + 1} - 2(Z/S)$
$R_V(Z/S) = 1.0/\sqrt{4(Z/S)^2 + 1}$

4 EM31 Observations

$$\sigma_{aH}(S) = \sigma_1[R_H(Z_0/S) - R_H(Z'_1/S)] + \sigma_2[R_H(Z'_1/S) - R_H(Z'_2/S)] + \sigma_3[R_H(Z'_2/S)]$$
$$\sigma_{aV}(S) = \sigma_1[R_V(Z_0/S) - R_V(Z'_1/S)] + \sigma_2[R_V(Z'_1/S) - R_V(Z'_2/S)] + \sigma_3[R_V(Z'_2/S)]$$

where $Z'_1 = Z_0 + Z_1$
$Z'_2 = Z_0 + Z_2$
$Z_0 = 0, 1$ metre

In addition to the assumption of low induction numbers, the electrical model in Figure 3 was further simplified by assuming that the contribution of the third layer, which represents the bedrock, is quite small and is fixed at 0.1 millisiemens/metre which is basically the noise level of both instruments. Hence, the problem is one of fitting ten observations to a theoretical model having four unknowns; namely, two conductivities and two thicknesses. Clearly, the standard method of solving this type of problem is a least squares inversion process. Hence, a computer algorithm was designed which minimized the sum of the squares of the differences between the observed σ's and the computed σ's.

When the process converged to the best 3-layer model for each set of soundings, the algorithm automatically terminated and a standard error between the observed and a theoretically computed model was evaluated.

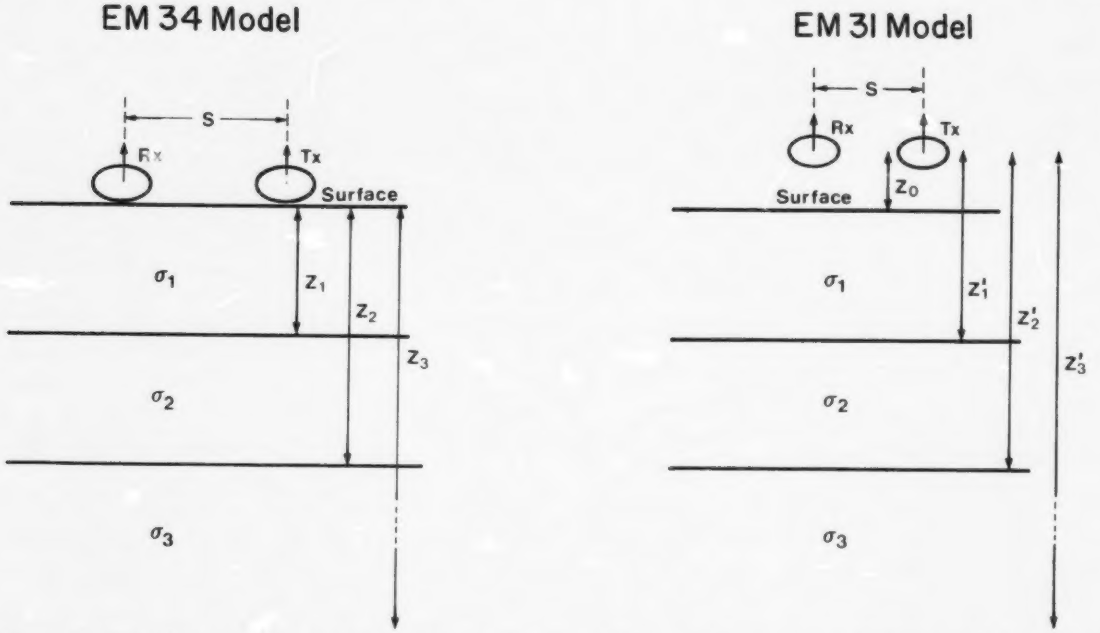


Figure 3. Electrical model used to represent the conducting overburden and bedrock for the ground electromagnetic measurements. (Project S64.)

FIELD PROCEDURE

Under ideal conditions electromagnetic soundings were carried out along two lines that were mutually orthogonal directly over each drill hole, using 10 m station intervals to check the validity of the horizontal layer model. Since the drill holes are adjacent to road access, many of the sites are near powerlines, metal fences, telephone cables, and other sources of electrical interference, thus restricting the number of observations at many of the sites. However, it is concluded that representative soundings were obtained at all the sites except holes 17 and 18, which are directly beneath a major transmission line and adjacent to the main highway.

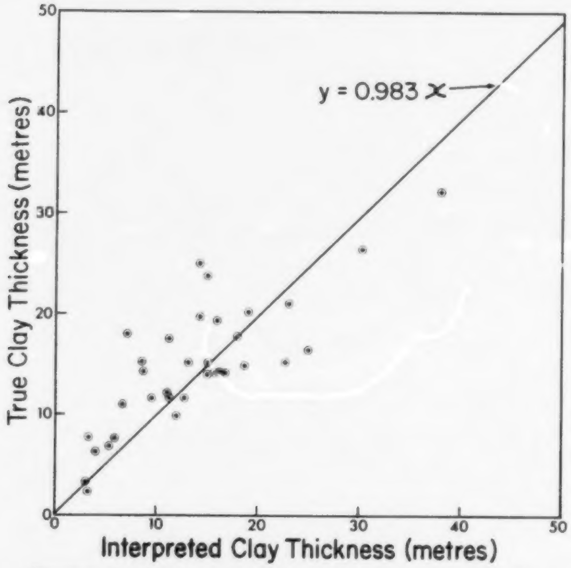


Figure 4. Upper clay layer thickness from drill logs versus the true clay layer thickness fitted to a straight line of the form y=mx. (Project S64.)

TABULATION OF RESULTS

In order to correlate the drill logs with the 3-conducting layer model, the upper layer and the sum of the thicknesses of the successive underlying layers was compared to the first and second layer thicknesses and conductivities, respectively (Table 2).

The following observations can be made from the tabulated results:

1. The logs indicate that a near-surface clay layer is present in all cases, except at holes 15 and 19. This result could have also been derived from the electromagnetic interpretation, since the upper layer conductivity is generally over 30 millisiemens/metre, except at hole sites 4, 22, 27, 32, 34, and 36. At these sites, however, less than 2 m of resistive material is interpreted to be present, which may correspond to a gravel road bed where the sounding was taken.
2. The interpreted clay layer thickness is in good agreement with the upper clay layer thickness. This conclusion is verified in Figure 4 where the upper clay thickness versus the interpreted thickness is plotted and fitted to the straight line whose equation is y = 0.983x. It should be noted

TABLE 2. SUMMARY OF 1984 SONIC DRILL LOGS AND GROUND ELECTROMAGNETIC DATA INTERPRETATION (PROJECT S64)
(c-clay; s-sand; t-till; g-gravel; p-peat; b-boulders)

	Drill Logs		EM Interpretation				
Hole No.	First Layer (metres)	Successive Layers (metres)	First Layer (mS/m)	(m)	Second Layer (mS/m)	(m)	Standard Error (mS/m)
1	14.0 (c)	17.6 (s,t)	42.0[1]	15.0	0.19	21.7	1.8
2	6.4 (c)	5.5 (s,t,c)	48.7[1]	4.0	3.0	$2.5x10^{4}$	1.9
3	2.4 (c)	33.5 (s)	24.3[1]	3.3	1.4	31.9	1.1
4	17.7 (c)	14.6 (s,c,t)	10.4	1.4	33.4[1]	18.0	0.5
5	15.2 (c)	14.6 (s)	48.8[1]	8.5	5.7	63.7	1.5
6	19.8 (c)	12.8 (t)	39.5[1]	14.4	5.9	914	1.0
7	16.5 (c)	18.9 (g,t,s)	36.8[1]	7.2	29.3[1]	17.8	1.2
8	9.9 (c)	11.9 (b,s,t)	41.8[1]	12.0	0.02	0.09	1.8
9	15.2 (c)	31.1 (s,t)	35.6[1]	15.1	13.8	26.9	1.4
10	11.6 (c)	36.0 (s,t)	39.6[1]	9.5	17.26	0.1	1.5
11	12.2 (c)	2.7 (t)	40.6[1]	11.2	0.8	$1.4x10^{5}$	2.2
12	6.7 (c)	17.7 (s,t)	36.4[1]	5.3	6.7	236.6	1.9
13	3.4 (c)	30.8 (t)	50.7[1]	3.1	0.2	910.4	1.7
14	20.1 (c)	14.9 (t,c,s)	35.5[1]	16.2	28.8	3.0	1.8
15	52.3 (s)	>9.6 (t)	0.1	5.8	22.2	6.1	0.7
16	23.8 (c)	7.9 (s,g)	33.7[1]	15.0	5.3	9.1	1.2
17	13.4 (c)	23.4 (s,t)	-	-	-	-	-
18	20.4 (c)	7.0 (s)	-	-	-	-	-
19	5.8 (s)	2.7 (t)	0.1	3.2	12.6	0.9	0.3
20	26.5 (c)	8.8 (t)	32.1[1]	30.4	0.01	114.4	2.4
21	53.3	22.9(s,t)	35.5[1]	4.7	26.4[1]	142.3	1.8
22	14.3 (c)	15.2 (s,t)	10.8	0.2	35.8[1]	16.1	1.4
23	17.5 (c)	7.9 (t)	33.8[1]	11.2	248.9	1.1	1.3
24	15.4 (p,c)	13.0 (t)	36.5[1]	22.6	1.4	$1.5x10^{4}$	1.6
25	11.0 (c)	24.4 (s,t)	44.6[1]	6.6	5.7	267.3	3.1
26	7.6 (c)	23.3 (s,t)	52.6[1]	3.4	9.7	$4.20x10^{3}$	1.5
27	15.5 (c)	33.5 (s,t,c)	5.8	0.9	25.8[1]	40.4	0.6
28	18.0 (c)	42.5 (t,s,c)	38.7[1]	7.1	16.2	$2.4x10^{4}$	1.4
29	11.9 (c)	13.1 (t,s)	41.1[1]	11.4	0.1	48.6	1.5
30	14.2 (c)	3.8 (t,s)	36.1[1]	7.3	28.6[1]	9.5	1.5
31	14.9 (c)	43.0 (s,t,c)	33.1[1]	18.7	10^{-4}	915.5	0.9
32	14.3 (c)	20.7 (s,c,t,b)	17.2	1.8	30.6[1]	15.7	0.8
33	7.6 (c)	22.0 (t)	47.4[1]	5.7	6.5	38.8	1.1
34	21.0 (c)	7.3 (t,b)	8.7	1.8	34.1[1]	23.2	0.4
35	12.8 (c)	39.0 (t,c,s)	37.5[1]	11.6	3.0	$1.9x10^{4}$	1.1
36	19.4 (c)	17.2 (t)	33.9[1]	16.0	0.02	73.5	1.8
37	25.0 (c)	25.0 (s,t)	29.7[1]	14.2	220.7	1.4	1.2
38	32.3 (c)	3.1 (s,t,c)	43.6[1]	3.4	28.7[1]	34.8	2.1
39	36.3 (c)	7.6 (t,s)	24.2[1]	79.8	22.6	0.3	2.8
40	15.2 (c)	5.2 (t,c)	3.1	0.6	41.1[1]	13.4	0.7
41	40.5 (c)	12.5 (s)	33.5[1]	84.8	10.3	$3.5x10^{3}$	3.0
42	14.3 (c)	Nil	40.4[1]	8.6	9.3	913.9	1.4

NOTE:
[1] Interpreted to be a clay layer.

that the thickness determinations for holes 21, 39, and 41 were not used for this analysis since the interpreted thicknesses of 142, 80, and 85 m, respectively, are well beyond the depth of investigation of the instrumentation, indicating that these layers are behaving, electrically, as half spaces. Furthermore, the hole 27 thickness determination was not used since a second 16 m clay layer only 11 m below the first layer was present, which invalidated the simple 3-layer model.

3. The ground electromagnetic technique was successful in a limited number of cases in defining the expected conductivity and thickness of the underlying layer. One such case would be hole 3 which had a thin upper clay layer of 2.4 m interpreted to be 3.3 m thick, underlain by 33.5 m of sand, interpreted to be 1.4 millisiemens/metre and 31.9 m thick. The explanation for this close match may be because the clay cover is quite thin, which is an easier case for electromagnetics than deriving parameters for resistive layers beneath several metres of conductive overburden.
4. The average conductivity for clay from Table 2 is 37.1 millisiemens/metre, which is consistent with other determinations.

CONCLUSIONS

Airborne electromagnetic results have proven to be extremely useful in the sonic drilling program for delineating areas of conductive overburden associated with bedrock valleys. Estimates of the clay layer thickness can only be evaluated by assuming an average conductivity, which in this case is 33.8 millisiemens/metre.

Ground electromagnetics in the vicinity of drill hole sites can be used to estimate clay layer thicknesses. Hence, in a profiling mode, electrical sections of the upper conducting layer can be actually mapped, which may in turn be used to map the underlying bedrock topography, if it reflects the same variations as the upper clay layer.

CURRENT ACTIVITIES

The sonic drilling program is continuing in 1985 throughout the other townships of the BRIM area, and both airborne and ground geophysics used in conjunction with the Quaternary and bedrock geology are being used to site the drill holes. The geophysical interpretation, therefore, is proving to be extremely useful in identifying zones containing potentially large Quaternary sections for overburden sampling, which is contributing to the success of the sonic drilling program. The success of the sonic drilling program can be best stated by the high incidence of till occurrences in the drill hole sections; 36 of the 42 holes drilled (i.e. 86%) contained some till, and 31 of the 42 holes drilled (i.e. 74%) contained at least 1 m of till, which is the material transported by glaciation that is most diagnostic to exploration geochemists interested in studying the mineral potential of the area.

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EASTERN REGION

39. Fault Locating with an Engineering Seismograph

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INTRODUCTION

A seismic survey project was initiated by the Regional Geophysicist, Tweed, Ontario, in the summer of 1985 to verify the location of faults identified on the Preliminary Paleozoic Geology Map P.2717 of the Russell-Thurso area, published in the spring of 1985 (Williams *et al.* 1985).

The work was done in support of the Ontario Geological Survey Paleozoic geology mapping project in Eastern Ontario being conducted by D.A. Williams from the Tweed District Office. The purpose was to obtain more fault information to help D.A. Williams locate, as precisely as possible, the major fault lines in the map area, particularly at fault junctions.

This fault project was an outgrowth of a seismic bedrock mapping project done in 1984 in the landslide area north of Casselman, Ontario (Kingston and Papertzian 1985). It was made possible by the previous development by the author of a seismic reflection technique for measuring depths over 20 m, using only a single channel engineering seismograph (Kingston and Papertzian 1985). Further modifications to the seismic system permitted rapid profiling of bedrock topography with a continuous line of spot depth-to-bedrock measurements.

The survey covered the southern part of Map P.2717. It consisted of 8 test sites to measure the velocities of the different rock formations and 11 profiles over faults or fault zones which were 144 m to 1200 m in length. In a 3 week period with 3 to 4 working days per week, 41 refraction and 38 reflection spreads, using 12 geophones, for a total of 79 spreads were completed. Of these, 35 refraction spreads were shot in the forward direction only because the depths were shallow and there was little or no dip to the bedrock. The other 44 spreads, both refraction and reflection, were shot in forward and reverse directions. These 79 spreads were equivalent to 124 conventional single hammer and plate seismic lines.

SEISMIC INSTRUMENT SYSTEM

The single channel engineering seismic instrument system and reflection technique developed by the author has been described in detail in a previous report (Kingston and Papertzian 1985). Basically the system consists of a Nimbus® ESR-125 single channel seismograph, a Nimbus® ESR-100 recorder, Mark Products® standard 50 Hz geophones, and a seismic energy source that fires 12 gauge slugs into the bottom of a 1 m deep hole.

The system has been further improved by the author by the addition of computer programs for seismic data processing, a 12-geophone cable with take-outs at 4 m intervals, a switch box for geophone selection and provision for 2 preamplifier and bandpass filter circuits. One filter is centred at about 100 Hz for hammer and plate refractions, which give signals predominantly between 80 and 125 Hz at this site. The other filter is centred at about 300 Hz for reflections using the 12 gauge energy source, which gives reflection signals predominantly between 250 and 330 Hz. This latter filter was not perfected in time for the field work.

The use of the 12-geophone cable still requires a separate shot for each geophone, but does permit rapid forward and reverse shooting, since the geophones do not have to be moved. In the reflection method, forward and reverse shooting allows the calculation of bedrock dip, but also gives a continuous series of depth points for bedrock profiling. A forward shoot gives an average depth of bedrock over the first half of the spread, while the reverse shoot gives an average depth over the last half of the spread.

In addition, the 4 m geophone spacing has many advantages over a 3 m, 6 m, etc. spacing used to replace imperial measures of 10 feet, 20 feet, etc. If needed, many more combinations of geophones are possible for arrays. A 4 m spacing gives essentially the same distance coverage as a 10-foot spacing, without sacrificing data point coverage, but is not as great as a 15-foot interval, which is considered too large. Fewer geophones and shots are needed for a given spread distance of 12 geophones. For example, at 4 m spacing 12 geophones and 12 shots cover 48 m. For the same distance using 3 m spacing, 16 shots and geophones would be needed. Also, selected optimum spreads are available for forward and reverse reflection shooting for different bedrock depths, which simplifies field procedures.

Programs have been developed for processing the seismic field data on an IBM® PC computer. The programs are designed for manual input of time and distance data points to accommodate the single channel system. The refraction program gives a printer plot of the data points for viewing purposes, a linear least squares solution of each selected line segment for velocity and time intercept, the calculated depth to each layer, and a printed output of the results. The reflection program calculates the squares of the times and distances, a linear least squares solution of the squared values, the average overburden velocity, the time intercept, and depth. A printed output of the results is also produced.

SEISMIC SURVEY METHOD

Seismic refraction and reflection methods are both useful for detecting a bedrock fault. With a higher energy source, the refraction method can be used for depths up to about 30 m, if the fault or fault zone is expressed by a bedrock depression, step, or scarp, or if there are different rock types on each side of the fault. The refraction method has the advantage that the bedrock velocity is also determined. The reflection method has the advantage that it can be used for bedrock depths >30 m, but it does not give the bedrock velocity. It can detect a fault only if the fault is expressed by a bedrock depression, step or scarp.

The refraction method can be applied in two different ways using the 12-geophone cable. First, a long forward refraction line can be done by placing the shot point at 0 m and the geophones at 4 m through 48 m. The cable and geophones are then moved forward and relocated at 52 m through 96 m to continue the line. This procedure can be repeated for a distance of 140 m or more, using the 12 gauge energy source. Bedrock depths of about 40 m can be measured under good ground conditions.

Second, for shallow depths up to about 15 m, forward and reverse shooting can be done easily and rapidly using a single 12-geophone spread. An ideal spread is to place the forward shot point at 0 m and the geophones at 4 m through 48 m as before. After shooting the forward spread (hammer and plate are sufficient), the shot point is moved to 52 m, and a reverse spread is shot without moving the geophones. The cable and geophones are then moved ahead, so that the 52 m shot point becomes the 0 m shot point for the next spread. Repeating this procedure gives a series of depth points and bedrock velocities which is ideal for locating a fault.

The reflection technique developed by the author gives spot depth-to-bedrock measurements using the "optimum window" of offsets (distances from the shot point to the geophones) described by Hunter *et al.* (1982). The "optimum window" identifies the minimum and maximum offsets where usable reflections can be obtained with little or no interference from other seismic events. The overall window is taken to be from an offset distance equal to half the depth to an offset distance equal to twice the depth. Analysis of reflection signals has shown that the best reflection signals are obtained between an offset distance about equal to the depth and an offset distance about equal to one and a half times the depth. For deep reflectors (over 30 m), the 12-geophone spread cannot cover the entire window. Therefore, an offset and spread is selected so that the 12-geophones have a minimum offset about equal to the depth and a maximum offset about equal to one and a half times the depth. For depths of about 30 m and greater, a useful and commonly used spread was found to be 100 m. In this spread, the forward shot point is at 0 m, the 12 geophones are at 4 m intervals from 28 m to 72 m, and the reverse shot point is at 100 m. For profiling, the spread is repeated by moving the cable ahead 100 m, so that the 100 m reverse shot point becomes the forward shot point of this next spread. For shallow depths from about 20 m to 30 m, an adequate spread is 60 m, and uses only 10 geophones. In this spread, the forward shot point is at 0 m, the geophones are at 12 m to 48 m, and the reverse shot point is at 60 m.

In the reflection method, the seismic trace for each geophone position is recorded on the ESR-100 single channel strip chart recorder. Usually some part of a reflection signal (a peak or trough) can be identified and correlated from trace to trace. Also, one or more complete reflection signals are usually obtained on each spread which give an accurate arrival time of the onset of the reflection wave. A peak or trough is used for manually determining the arrival times from the chart record. The time of the peak or trough is corrected to the time of the onset of the reflection by measuring the period of the reflection wave.

Depth calculations are done following the method described by Huntec (1972). A plot of the squares of the arrival times versus the squares of the offset distances gives a straight line for true reflections. The square root of the inverse of the slope of the line gives the average velocity of the overburden above the bedrock. The square root of the ordinate intercept gives the travel time of a shock wave vertically below the shot point. From these data, the depth- o-bedrock is easily calculated. This data processing is done by computer.

FIELD PROGRAM

The field program was done in two parts. First, refraction lines were done at selected test sites in areas of bedrock outcrop where the bedrock was at shallow depths. This was done to determine velocities for the different bedrock formations (Queenston, Carlsbad, Billings, Lindsay, Verulam, Bobcaygeon, and Gull River) for interception purposes. Second, profiles were run over selected fault locations by making a continuous series of spot depth-to-bedrock measurements. The preferred areas recommended by D.A. Williams were at or near fault junctions (personal communication). Sites were selected that were away from housing areas, major traffic routes and rough, irregular topography. Three profiles were at locations where no faults were shown on map P.2717, but where the existence of faults was subsequently postulated by D.A. Williams (personal communication). A previous seismic survey of the bedrock in the Lemieux-Casselman area (Kingston and Papertzian 1985) provided additional information and control for this field program. The test site and profile locations are shown on Figure 1.

FIELD PROCEDURES

The general field procedure was first to estimate the depth of bedrock by visual inspection of the area for outcrops, drilling auger holes, or shooting a trial spread.

At test sites, the refraction method was used exclusively regardless of the bedrock depth, in order to measure the bedrock velocity. For shallow depths (up to about 7 m), a hammer and plate were used as the energy source. For greater depths (up to about 40 m), a 12 gauge energy source was used and the 12-geophone spreads were extended until bedrock arrivals were obtained.

At profile sites with shallow depths, the refraction method was used in order to get a velocity to identify the bedrock formation. For very shallow depths (from 1 to 6 m), a hammer and plate were used as the energy source. For depths up to about 16 m, a 12 gauge energy source was used. For these refraction profiles, the spreads were shot in the forward direction only.

At profile sites with greater depths (usually >30 m but as shallow as 24 m), the reflection method was used with a 12 gauge energy source. All reflection spreads were shot both forward and reverse to give two depth points per spread. Profiles were ex-

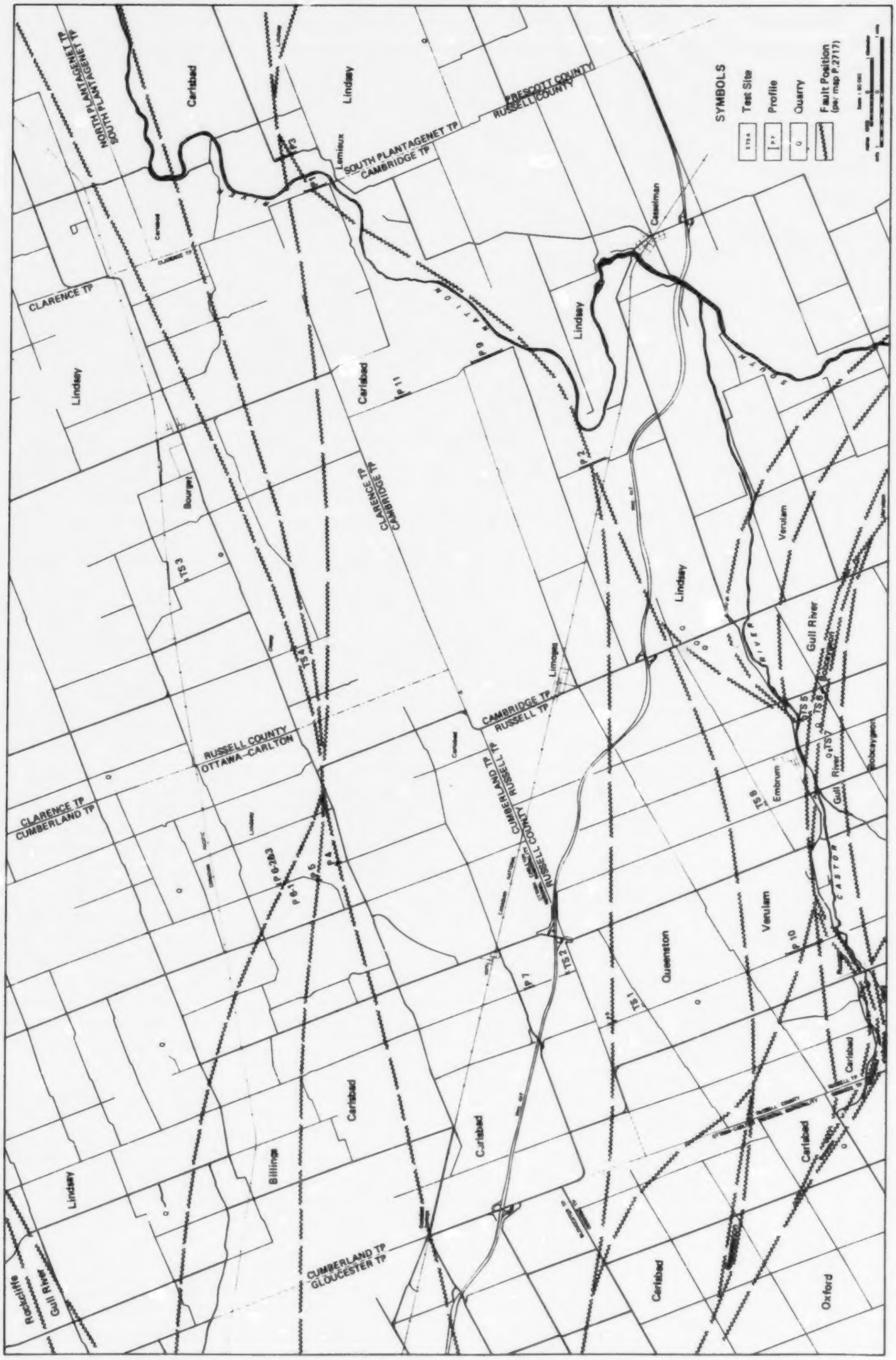

SYMBOLS
Test Site
Profile
Quarry
Fault Position (per map P.2717)
NORTH PLANTAGENET TP
SOUTH PLANTAGENET TP
SOUTH PLANTAGENET TP
CAMBRIDGE TP
PRESCOTT COUNTY
RUSSELL COUNTY
CLARENCE TP
CLARENCE TP
CAMBRIDGE TP
CAMBRIDGE TP
RUSSELL TP
RUSSELL COUNTY
OTTAWA-CARLTON
CLARENCE TP
CUMBERLAND TP
CUMBERLAND TP
RUSSELL TP
RUSSELL COUNTY
CUMBERLAND TP
GLOUCESTER TP
Casselman
Lemieux
Bourget
Limoges
Embrun
Carlsbad
Lindsay
Verulam
Gull River
Queenston
Billings
Rockcliffe
Oxford
Bobcaygeon
SOUTH
RIVER
CASTOR
NATION
TS 1
TS 2
TS 3
TS 4
TS 5
TS 6
TS 7
TS 8
P 1
P 2
P 3
P 4
P 5
P 6-2&3
P 7
P 9
P 10
P 11

Figure 1. Map of seismic survey area showing test sites and profile locations. (Project 39.)

tended until visual inspection of recorded data indicated that a subsurface feature or change in bedrock had been traversed.

RESULTS

A summary of the results of test sites and profiles done by the refraction method is given in Table 1. A summary of the results of profiles done by the reflection method is given in Table 2.

The refraction results in Table 1 show that any one formation exhibits a large variation in velocity depending on layering, depth, weathering, etc. The ranges of velocities for the different formations are as follows:

FORMATION	VELOCITY RANGE (m/s)
Queenston	2050 - 3060 (weathered) 3340 - 3360
Carlsbad	1960 - 2990 (weathered) 3280 - 4400
Billings	2390 (weathered) 3340 - 3350
Lindsay	3680 (weathered) 5360 - 5610
Verulam	4670 - 5630
Bobcaygeon	5190 - 6940
Gull River	3600 - 3960

Since different fault blocks undoubtedly have different horizons in the same formation at different locations, too much reliance cannot be placed on the velocities measured at the test sites to identify the rock formations elsewhere. It is better to assess the velocity difference at the location being investigated.

Eight of the eleven profiles traversed faults shown on map P.2717. Profiles P7, P9, and P11 were at other possible fault locations identified by D.A. Williams (*see* Figure 1.).

Two unexpected features in the seismic field data proved to be useful for detecting faults. First, in shallow refraction spreads, there was usually a sudden change from a 2-layer case (topsoil over bedrock) on the higher side of the fault to a 3-layer case (topsoil over till over bedrock) on the lower side of the fault. The topsoil thickness remained the same on both sides of the fault but a layer of till made up for the increase in depth to bedrock on the lower side. Second, in deep reflection profiles, when shooting a spread into a scarp face, the plotted data were completely inconsistent with data from other spreads and gave ficticiously high velocity and depth values.

The interpretation of the seismic results was done in consultation with D.A. Williams who is in agreement with the results presented in this report. For simplicity, the results of short, shallow refraction profiles P4, P5, P6, P7, and P8 are given by written description. The results of longer profiles P1, P2, P3, P9, P10, and P11 are shown as bedrock topographic sections in Figure 2. In refraction profiles, the depths are arbitrarily plotted at a distance of 5 m from the shot point. This is an average offset distance for the depth calculated by the refraction method. In reflection profiles, depths are plotted at the mid-point of the offsets where waves are reflected from the bedrock surface to the geophones. For example, on a 100 m spread the shot points are at 0 m and 100 m, while geophones are at 28 m to 72 m. For a forward shoot, waves are reflected from bedrock at distances from 14 m to 36 m. The mid-point is 25 m. Similarly, for a reverse shoot, the mid-point is 75 m. The depth is more appropriately plotted at the mid-point than the shot point, because data from a forward shoot cover bedrock over the first half of the spread, while data from a reverse shoot cover the last half of the spread. Also, the depth calculation method averages the bedrock depth and assumes a horizontal layer over the half spread. With depth points every half spread, better profile plotting is achieved.

Profile 4 consisted of 3 refraction spreads of 52 m, each shot from north to south. Carlsbad shale was mapped on both sides of the fault. Flat lying, thin bedded Carlsbad shale was exposed in the bottom of the road ditch alongside the northern two spreads. A slight hump in the bedrock of about 0.8 m was indicated by the seismic data near the south end of the second spread. But the overall depth of 2 m did not change significantly over the three spreads. There was no significant evidence of a fault. If the fault exists, it is probably at or near the end of the second spread, and is at the same location as on map P.2717.

Profile 5 consisted of 3 refraction spreads of 52 m each, shot from south to north. Carlsbad shale was exposed just below the surface in the creek bed just south of the seismic profile. Carlsbad shale was mapped on the southern side of the fault and Billings shale on the northern side. The seismic data indicated the fault was at or near the end of the first spread. The evidence was a 3 m drop in the bedrock, an increase in bedrock velocity, and change from a 2-layer case (over Carlsbad) to a 3-layer case (over Billings shale) with a till over the deeper Billings shale. This supports the existence of the fault as shown on the map.

Profile 6 was done in 2 sections, with one spread south of a creek and a double spread north of the creek. Billings shale was mapped on the southern side of the fault (at the creek) and Lindsay limestone on the northern side. Further to the south of the profile, Billings shale was only about 0.5 m below the surface. The seismic data indicated Billings shale south of the creek at a depth of about 6 m and Lindsay limestone north of the creek at a depth of about 14 m. Evidence for the fault being at the southern side of the creek was a steep slope on the southern bank of the creek, large boulders of Lindsay limestone in the bottom of the creek, and an 8 m drop in bedrock from the southern side to the northern side of the creek. This supports the fault as shown on the map.

Profile 7 consisted of 4 spreads of 52 m each, shot from south to north. Carlsbad shale was mapped on both sides of the fault. Outcrops of Carlsbad shale just south of the profile area along Highway 417 contain sandstone layers (D.A. Williams, personal communication). Along the road of profile 7, pieces of thick-bedded Carlsbad shale had been dug up during the recent placement of new utility poles. Bedrock was about 2 m below road level. High seismic velocities indicated dense limestone or sand-

TABLE 1. SUMMARY OF SEISMIC REFRACTION RESULTS (PROJECT 39.)

Profile No. & Direction	Spread (m)	Velocity (m/s)	Depth FWD	(m) RVS	Bedrock Formation	Remarks
TS1 W-E	52	2050	3	2	Queenston	Weathered
		3340	7	7	Queenston	
TS2 N-S	52	3940	5	8	Carlsbad	Sandstone
TS3 N-S	52	5610	12	14	Lindsay	
TS4 S-N	96	5360	31		Lindsay	North of Fault
TS5 E-W	48	3960	0		Gull River	Outcrop
TS6 W-E	100	5370	20	22	Bobcaygeon	
TS7 N-S	48	3600			Gull River	Velocity Only
TS8 W-E	144	4670	40		Verulam	
P4-1 N-S	52	3380	2		Carlsbad	
P4-2 N-S	52	4000	2		Carlsbad	0.8 m Ridge
P4-3 N-S	52	3480	2		Carlsbad	
P5-1 S-N	52	3150	3		Carlsbad	
P5-2 S-N	52	3350	6		Billings	
P5-3 S-N	52	3340	6		Billings	
P6-1 S-N	48	2390	6		Billings	Weathered
P6-2 S-N	48	3680			Lindsay	Weathered
P6-3 S-N	68	3680	14		Lindsay	6-2 + 6-3
P7-1 S-N	52	4000	2		Carlsbad	
P7-2 S-N	52	4120	2		Carlsbad	
P7-3 S-N	52	4400	2		Carlsbad	
P7-4 S-N	52	5820	2		Carlsbad	Sandstone
P8-1 N-S	52	2990	5		Carlsbad	Weathered
P8-2 N-S	52	2620	3		Carlsbad	Weathered
P8-3 N-S	52	2920	7		Queenston	Weathered
P8-4 N-S	52	3060	6		Queenston	Weathered
P10-1 S-N	72	2900	9		Queenston	Weathered
P10-2 S-N	48	3360	13		Queenston	
P10-3 S-N	48	2230	7		Carlsbad	Weathered
P10-4 S-N	48	1960	7		Carlsbad	Weathered
P10-5 S-N	48	6560	15		Bobcaygeon	
P10-6 S-N	48	6940	15		Bobcaygeon	Spreads at
P10-7 S-N	48	5190	13		Bobcaygeon	100 m intervals
P10-8 S-N	48	3280	12		Carlsbad	for this
P10-9 S-N	48	3640	13		Carlsbad	Profile
P10-10 S-N	48	4000	15		Carlsbad	
P10-11 S-N	48	4000	14		Carlsbad	
P10-12 S-N	48	5630	16		Verulam	

Note: Depth is depth below road level.

stone layers in the Carlsbad. The only suggestion of a fault from the seismic data was an increase in velocity between the first two and last two spreads, and a slight depth variation. If the fault exists, it is most likely associated with the third spread and is at the same location as identified by D.A. Williams (personal communication).

Profile 8 consisted of 4 spreads of 52 m each, shot from north to south. Carlsbad shale was mapped on the northern side of the fault and Queenston shale on the southern side. The seismic data indicated the fault between the first two and last two spreads. Evidence was an increase in bedrock depth of about 4 m, a slight increase in velocity, a change from a 2-layer case (over Carlsbad) to a 3-layer case (over Queenston) with a till layer over the deeper Queenston shale, a change from brown soil with pieces of grey shale, at the northern end of the profile, to red soil with pieces of red Queenston shale, near the end of the second spread. This supports the presence of the fault as shown on the map.

The bedrock profiles shown in Figure 2 are ordered top to bottom from the east (near Lemieux) to the southwest (near Russell). Profile P1 is the most significant. A fault is known to exist just north of the South Nation River at Lemieux. The evidence is that

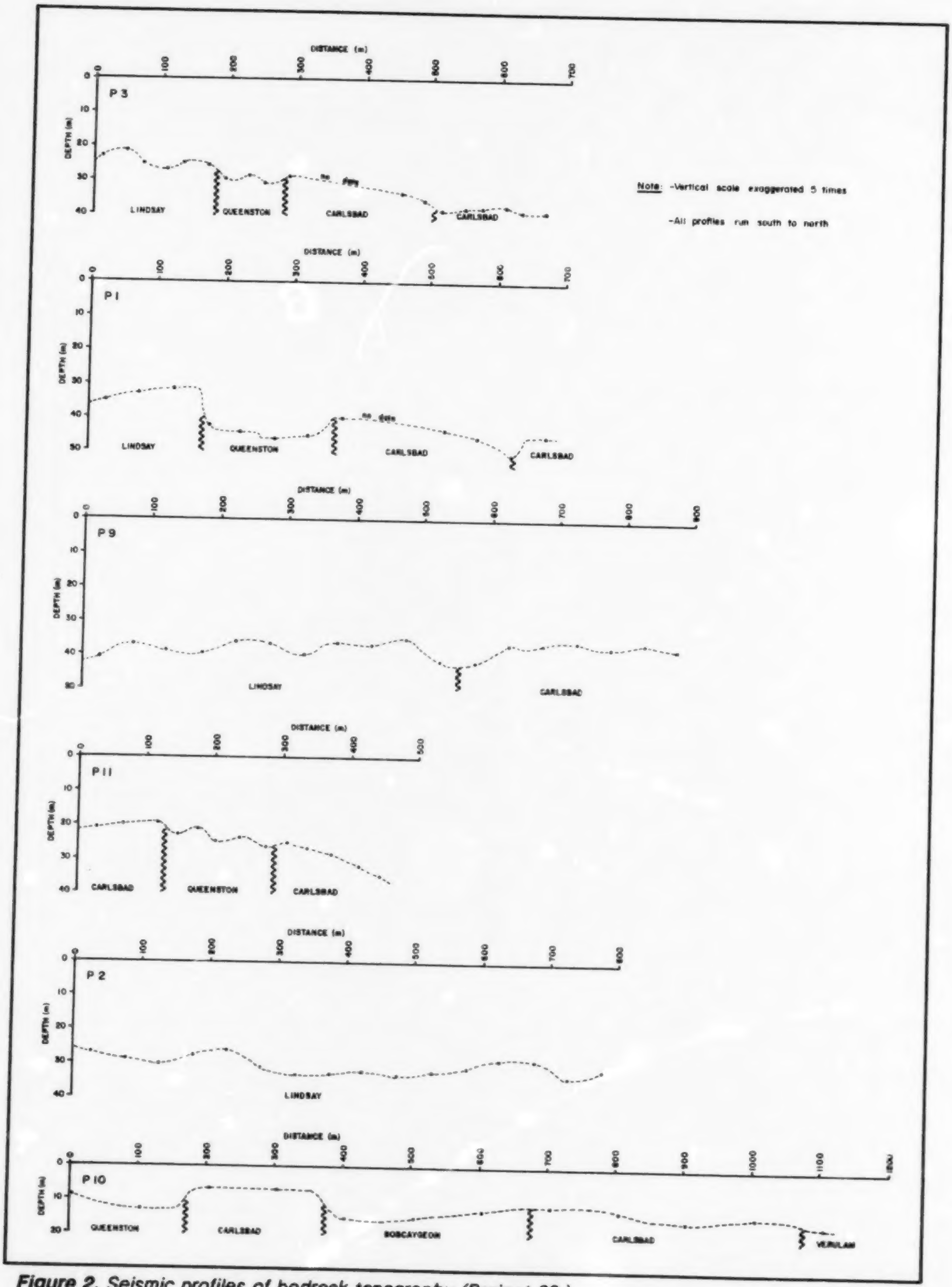
TABLE 2. SUMMARY OF SEISMIC REFLECTION RESULTS (PROJECT 39.)

Profile No. & Direction	Spread (m)	Depth FWD	(m) RVS	Remarks
P1-1 S-N	100	35	34	
P1-2 S-N	100	32	42	FWD Depth 32 m (1984)
P1-3 S-N	100	44	46	
P1-4 S-N	100	45	40	100 m gap after P1-4
P1-5 S-N	100	44	45	
P1-6 S-N	100	50	45	RVS Depth 44 m (1984)
P2-8 S-N	100	27	29	
P2-7 S-N	100	30	28	
P2-1 S-N	100	26	31	
P2-2 S-N	100	33	33	
P2-3 S-N	100	32	33	
P2-4 S-N	100	32	31	
P2-5 S-N	100	29	29	
P2-6 S-N	100	33	31	
P3-1 S-N	60	23	22	
P3-2 S-N	60	25	26	
P3-3 S-N	60	25	26	
P3-4 S-N	60	30	29	
P3-5 S-N	60	31	28	140 m gap after P3-5
P3-6 S-N	60	34	35	
P3-7 S-N	60	38	38	
P3-8 S-N	60	38	37	
P3-9 S-N	60	38	39	
P9-1 S-N	100	41	37	Lindsay at 37 m (1984)
P9-2 S-N	100	39	40	
P9-3 S-N	100	36	37	
P9-4 S-N	100	40	36	
P9-5 S-N	100	37	35	
P9-6 S-N	100	42	42	5 m Depression
P9-7 S-N	100	37	36	
P9-8 S-N	100	36	37	
P9-9 S-N	100	36	37	200 m North Depth is 25 m (1984)
P11-1 S-N	100	21	20	
P11-2 S-N	60	20	23	
P11-3 S-N	60	22	25	
P11-4 S-N	68	24	26	
P11-5 S-N	68	26	27	
P11-6 S-N	68	29	32	
P11-7 S-N	68	35		FWD only

Note: Depth is depth below road level.

the bedrock in the river (which is exposed in the summer) drops off suddenly just north of Lemieux where the river turns northward. Also, the seismic survey, done in 1984 (Kingston and Papertzian 1985) showed a drop of about 12 m in the bedrock between a point about 0.3 km north of the river and a point about 0.8 km north of the river. In addition, the 1984 seismic work proved the bedrock south of the fault (and in the river) was Lindsay limestone. Further, D.A. Williams proposed that a block of Queenston shale existed between the Lindsay on the south and the Carlsbad shale on the north (personal communication). Profile P1 shows a down-faulted block about 200 m wide that is taken to be Queenston shale. At the south-side fault, the Lindsay forms a scarp about 12 m high. At the north-side fault, the Carlsbad forms a small scarp about 4 m high. Towards the north, the Carlsbad increases in depth about 10 m to a pronounced trough truncated by a scarp about 5 m high on the north side. This is taken to be a fault in the Carlsbad. Profile P1 starts 65 m north of Concession 1 Road. The faults are, therefore, located at about 140 m, 415 m, and 695 m north of Concession 1 Road.

Profile P3 is just east of P1 but very near a fault junction. It exhibits the same fault pattern as P1 but the faults are closer together and the changes in depth to bedrock are less pronounced. P3 ends about



Note: -Vertical scale exaggerated 5 times

-All profiles run south to north

Figure 2. Seismic profiles of bedrock topography (Project 39.)

100 m south of the northern corner of the road (*see* Figure 1). The northern-most fault in the Carlsbad is about 280 m south of the corner of the road. The down-faulted block of Queenston is only about 100 m wide. The north-side fault is about 400 m south of the corner of the road, and the south-side fault is about 500 m south of the corner.

Profile P9 is west of P1, north of the South Nation River and north of the fault shown on map P.2717. The 1984 seismic survey showed that the bedrock on both sides of the river was Lindsay limestone. Therefore, a fault could not exist as shown on the map. Profile P9 shows that the fault between Lindsay on the south and Carlsbad on the north is expressed by a 6 m depression about 150 m wide, centred about 500 m north of the start of the profile or 1 km north from the corner of the road.

Profile 11 is a continuation of P9 about 1.9 km to the north. The 1984 seismic survey information shows that north of P9 the Carlsbad rises gradually from a depth of about 36 m to 25 m at a point 750 m northward, and then to about 25 m at the start of P11. Profile P11 exhibits a fault pattern similar to P1 and P3 with the exception that Carlsbad is on the south as well as the north of the Queenston fault block. The Queenston fault block is about 200 m wide and is centred on Concession 1 Road.

Profile P2 is significant because it shows no evidence of a fault. Profile P9 shows that the fault between the Lindsay on the south and the Carlsbad on the north is further to the north.

Profile P10 is very close to a major fault junction. It starts 200 m north of an abandoned railway line. Bedrock is at a shallow depth so the refraction method was used to obtain bedrock velocities as well as depths. The seismic data show that 4 faults were traversed by the 1.2 km profile. The profile shows an uplifted block of Carlsbad about 200 m wide with a fault on the southern side at about 175 m, and on the northern side at about 375 m. The bedrock velocity south of the first fault indicates Queenston shale rather than Carlsbad or Gull River. North of the second fault, a high bedrock velocity indicates Bobcaygeon and not Carlsbad. Another fault is identified at about 675 m on the profile, where a sudden decrease in velocity indicates Carlsbad shale. Again at about 1075 m on the profile another fault is identified by a sudden increase in velocity which indicates Verulam limestone to the north. These results indicate that a narrow block of Bobcaygeon, about 300 m wide, continues west of the fault junction shown on the map, and divides the block of Carlsbad.

In general, the seismic profiles confirm faults as shown on map P.2717. However, profiles P2 and P9 show that the fault between Lindsay limestone and Carlsbad shale, running southwest from Lemieux, is farther north than mapped. Also, profiles P1, P3, and P11 show that a narrow block of Queenston shale runs from north of Lemieux westerly nearly along Concession 1 Road. Profile P7 indicates this fault could continue westerly south of Vars, but there is no evidence of Queenston shale at this location. Profile 10 shifts slightly the fault locations between the Queenston and Carlsbad, and Carlsbad and Verulam. Also, it shows a block of Bobcaygeon within the area west of the fault junction mapped as Carlsbad. This information will be of value in the preparation of a final Paleozoic geology map of the area.

CONCLUSIONS

1. This project demonstrated that a single channel seismic system as modified by the author is capable of profiling bedrock topography by a series of spot depth measurements made at 50 m intervals or less.
2. Seismic profiling as done in this survey is an effective way to locate a fault if there is a significant topographic expression (downfaulted block, step or scarp, depression) or different rock types on each side of the fault.
3. The reflection technique developed by the author permits rapid profiling of bedrock topography at depths greater than can be achieved by the refraction method. The technique, which gives spot depth measurements, works most effectively for depths >30 m. Depths of about 50 m were measured on this survey, but even greater depths are achievable.
4. Identification of several faults (or lack thereof) in the survey area will aid the Ontario Geological Survey Paleozoic mapping project and D.A. Williams in the preparation of the final Paleozoic geology map of the area.
5. The seismic survey provides additional information on bedrock topography in the landslide area north of Casselman, Ontario, and will allow updating of the bedrock map prepared in 1984.
6. More seismic work in the map area is needed to fully resolve the fault patterns.

ACKNOWLEDGMENTS

To Tom Fletcher, Regional Mines Coordinator and Paul Kingston, Regional Geologist, Ontario Ministry of Natural Resources, who supported this survey.

To Dave Williams, who assisted in planning the field program and interpreting the seismic results.

To Robert Brunette, Operations Manager, Larose Forest Headquarters in Bourget, Ontario, who provided living accommodations during the survey.

To Rick Renouf, who assisted in the field work and data processing, compiled the data processing programs for the IBM® PC computer, and prepared the figures accompanying this report.

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